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SPECTRA OF NOVA LACERTAE SECURED WITH THE 74-INCH TELESCOPE OF THE DUNLAP OBSERVATORY
The upper three show the photographic region of the spectrum, the remaining two both photographic and visual regions.

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NOVA LACERTAE

(With Plate XXII)

By R. K. YOUNG

THIS star was discovered independently by several observers but the first news of its discovery was received here midnight, June 18-19, in a telegram from the Harvard College Observatory announcing its discovery by L. C. Peltier, Ohio.

Its position (1900) is R.A. 22 h., 12.0 m., Dec. 55° 7′. The preliminary announcement called the star Nova Cephei. The accurate position, however, shows that it lies just wtihin the borders of the constellation Lacerta, so that it is now known as Nova Lacertae. On June 19th it had a magnitude of 2.4. A photograph of the region on a panchromatic plate taken by Dr. P. M. Millman on the night of the 19-20 shows that it was then of 2.2 magnitude or brighter. On the 21st it had faded to 3.0 and now, June 24th, it is about 4th magnitude.

Figure 1 shows a map of the sky prepared by Miss R. Northcott. The nova is indicated by a cross. Several of the stars bear numbers. These are the magnitudes of the stars given to the tenth of a magnitude with the decimal point omitted. Amateurs may use this map for following the changes in the brightness of the nova. Estimates of magnitude should be sent in to the A.A.V.S.O., Harvard College Observatory, Cambridge, Mass., stating what comparison stars were used.

Immediately on the receipt of the telegram announcing the discovery spectrograms were secured with the one prism spectrograph on the morning of June 19th and plates have been secured on every night since to the date of writing, June 24. Plate XXII, prepared by Dr. P. M. Millman, shows five spectra secured on June 20, 21, 22. The upper three are taken with the 25-inch camera and the lower two with the 12.5-inch camera.

An examination of the plates taken on June 19 shows diffuse absorption with high negative velocity about 1075 km/sec. The spectrum was similar to α Cygni type A2 with lines of H, FeII, MgII, and CaII. The interstellar lines of calcium were very sharp and strong.

The first spectrum reproduced is one taken with a very long slit on the morning of June 20. The spectrum is still of the α Cygni type. The absorption lines have a complex structure. It can be seen from the cut that the stellar calcium is displaced to the violet a little less than half the distance between the interstellar calcium lines. The

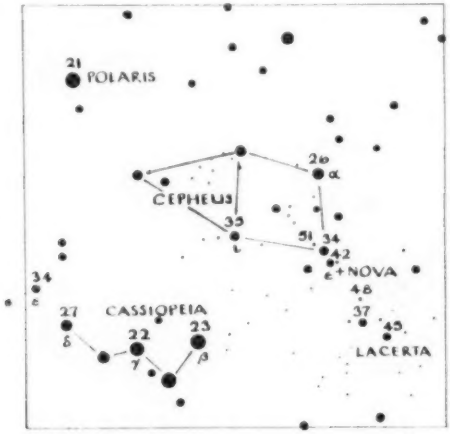

Fig. 1.—Map of the region near Nova Lacertae, (the nova indicated by a cross). Numbers are Harvard photovisual magnitudes given to the nearest tenth magnitude with the decimal point omitted.

strongest lines are those of H, FeII, MgII, CaII. Both interstellar Ca and Na are present. These are indicated in the plate by arrows.

The second spectrum reproduced was taken on the morning of June 21. The absorption spectrum is gradually changing to one of emission bands bordered on the violet side by complex absorption. The negative velocity indicated by the absorption lines is greater than on the previous night being measured by Dr. Millman as 1510 km/sec. as against 1180 km/sec. for June 20.

On the third spectrum taken June 22 the emission bands are much stronger. The strongest are due to H, FeII, CaII, and NaI. The absorption lines now indicate a velocity of approach of about 1690 km/sec. There are indications of faint absorption at the centre of the emission bands.

The last two spectra reproduced are taken with the 12.5-inch camera and extend down to the wave-length 6300. The interstellar line of sodium may be seen on these spectra.

Subsequent spectra taken on June 23 and 24, not reproduced, show that the emission bands are growing stronger with definite central absorption and on plates taken on the 24th this absorption appears double. The negative velocity of the absorption lines indicated on June 23 was 1820 km/sec. and on June 24, 1930 km/sec.

The velocities given above are for the absorption component, which is the strongest in most cases. Other absorption components show similar accelerations, notably one with a negative velocity in the neighbourhood of 3000 km/sec.

David Dunlap Observatory,
June 24, 1936.

THE SPECTROSCOPIC BINARY H.D. 34762

By WALTER H. STILWELL

THE star H.D. 34762, (Boss 1273), R.A. (1900) $5^h\ 14.7^m$, Decl. (1900) $+27°\ 51'$ was announced as a binary by Young in 1920.* The spectral class is B9. Its visual magnitude is 6.30 and its galactic co-ordinates are $l = 146°$, $b = -4°$. The four early plates taken by Dr. Young with a one-prism spectrograph at Victoria gave a total range from +36.6 km./sec. to −28.8 km./sec. This approximates the maximum range as determined from subsequent observations on plates obtained during the past winter by observers at the David Dunlap Observatory.

H.D. 34762 is an early-type star and consequently shows few measurable lines. Those which can be measured are, as a rule, quite broad and fuzzy; and on the majority of plates only one or two lines can be measured with much confidence. Hγ and Hδ were measured on every plate and are usually fairly well defined. Of the 13 plates 29 measures were made, and the mean probable error of a single plate, determined by comparison of the velocities of the individual lines, is ±12.8 km./sec. On the final radial velocity curve of the binary the mean residual is less than this, amounting to 10.4 km./sec. The nature of the lines measured accounts for the large probable error and the large scattering of the points about the curve.

The preliminary elements were obtained from standard curves and also by the Lehman-Filhés method. The eccentricity is very small and therefore, because of the small number of plates and the large scatter of the points and the consequent uncertainty of the curve, it was decided to use an eccentricity equal to zero for a preliminary solution. Using the present value of the period the number of revolutions since the date of discovery is of the order of 1150, but there is a possibility of there being an error of 2 or 3 periods in the total number. It is hoped that further observations may be made.

Two tables of data follow. The first table gives the plate number, the Julian Day of the observation, the radial velocity

*D.A.O., vol. 1, p. 168, 1920.

reduced to the sun, the number of lines measured on each plate, the number of times the plate was measured and the final residuals. The second table gives the preliminary elements adopted in making a differential correction and the final elements resulting from two

TABLE I

DATA ON SPECTROSCOPIC BINARY H.D. 34762

Plate	J.D.	V_0	No. lines measured	No. measures of plate	Final residuals
..	2421902.921	− 1.3 km/sec.			
..	948.876	+24.5			
..	958.801	+36.6			
..	2421965.782	−28.8			
514H	2428142.754	+43.6	6	3	+14.5 km/sec.
526H	160.686	−36.8	4	2	−27.3
546M	165.657	+11.5	7	1	+ 8.9
562H	167.667	−26.1	6	1	−14.4
578M	182.692	− 7.7	3	2	+ 9.2
584H	184.575	+16.7	3	1	+11.3
589H	184.756	+30.2	5	2	+19.4
593Hd	186.632	+14.2	4	2	− 7.2
597H	191.490	+46.5	1	3	+16.5
598H	191.714	+22.4	6	2	− 4.9
600H	195.535	+ 0.2	6	2	− 8.8
605M	196.562	+48.1	4	3	+18.8
617Y	201.579	+11.6	6	2	−12.7
624Hd	206.599	+15.2	6	2	− 0.1
630Hd	211.581	+19.9	7	1	+16.9
634Hd	214.549	−14.4	3	3	−13.6
638Hd	218.529	+32.3	8	1	+ 2.7
645H	219.514	+ 2.4	4	1	− 9.8
649Hd	220.528	− 9.1	6	1	+ 5.0
658M	221.515	−14.1	4	1	+ 3.7
677Y	229.504	+30.2	7	2	+ 1.4
678Y	229.539	+34.2	6	2	+ 5.7
691M	234.583	+18.6	6	1	−10.9
699M	238.531	+ 9.4	4	1	+10.6
702M	2428253.539	−13.5	3	1	+ 6.5
				Mean	10.4

Plates 584H and 597H were very weak, owing to clouds, and were not used in the solutions.

least squares solutions. The least squares solution was made using all the observations individually rather than combining them into normal places, because of the uncertainty of grouping observations of large scatter. In these elements T signifies the time at which the velocity is zero when changing from negative to positive, in other words it is the time of closest approach to the sun.

TABLE II

ELEMENTS OF H.D. 34762

Elements	Preliminary	Final
P	5.420 days	5.4197 days
K	32.5 km/sec.	(25.5±2.59) km/sec.
γ	+ 3.5 km/sec.	(+4.8±1.86) km/sec.
e	0.00	0.00
ω	270°	270°
T	1935 Dec. 4^d692	1935 Dec. 4^d695±0.002
$a \sin i$	2,400,000 km.	1,900,000 km.

The sum of the squares of the residuals was reduced by about 14.6% in the first least squares solution while the final solution further reduced this by only 0.05%.

David Dunlap Observatory
University of Toronto
June 5, 1936.

SUNSPOTS AND WEATHER FORECASTING IN CANADA*

By Andrew Thomson

VARIATIONS in the number of sunspots have long been known to be accompanied by changes in the earth's magnetic field, in the brilliancy of aurora and in the strength of electric currents in the earth's crust. Because of these established connections between sunspots and terrestrial phenomena, numerous attempts have been made to detect similar relationships with weather conditions. As the sun is the sole source of the energy that moves vast approximately homogeneous masses of air from one region to another and that evaporates enormous quantities of water required to form rain, it is reasonable to expect that changes in the sun's state would be accompanied by changes in the weather over the whole surface of the earth. Although it has recently been claimed that a close connection exists between sunspots and temperature, rainfall and thunderstorms at various stations in Canada, (1) hitherto at only a few isolated tropical stations have changes in weather been known to follow regularly year by year changes in sunspot numbers. The period for which meteorological observations have been taken at these stations has not extended more than two or three sunspot cycles. The most famous example of a harmony between sunspots and weather was the water level of the great lakes in Central Africa from 1902-1921(2) after which the agreement has broken down, supposedly due to the deepening of the Shire River.

The dependence between weather and sunspots is claimed to be due to ultra-violet light being emitted in greater amounts at times of sunspot maximum than at times of sunspot minimum.

It is highly probable that ultra-violet light ionizes the upper atmosphere, and it is suggested that the resulting free electrons diffuse downward into the troposphere, producing increased cloudiness and other related changes in weather. In view of the importance of this subject, the climatological records from a number of Canadian stations have been examined to determine if precipitation, temperature and other meteorological elements fluctuate either directly or

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inversely with sunspots. All the stations employed had long records and the data were known to have been taken by careful observers.

Forecasting Sunspot Numbers

Many sunspot-weather investigations are undertaken by amateur scientists to determine a method of weather forecasting for a period of one to ten years in advance. This weather forecast is on the basis of the number of sunspots, which is taken for granted as more or less definitely known, that will be found on the sun's disc at the time the forecast is expected to be verified. Before studying the connection between sunspots and past weather records, the primary question of forecasting the number of sunspots themselves will be discussed.

The record of sunspots which is almost universally accepted is that published by the director of the Eidgenössische Sternwarte, Zurich, Switzerland, and is now based on the observations taken by twenty observatories distributed over the earth's surface. The sunspot activity is given by the so-called Wolf relative spot number (r) where

$$r = k(10g + f).$$

In this formula k is a reduction factor on Wolf's unit, varying with the instrument, the observer and the mode of observation; g indicates the number of observed groups (centres of activity); and f the total number of single spots and spot nuclei. The factor k now used at Zurich to reduce the observations to the basis originally employed by Prof. Wolf is 0.60, since smaller nuclei are counted than formerly and the large umbra spots are broken up into various nuclei.

The earlier observations of sunspots going back to 1749 have been computed on the basis given above by the observatory at Zurich, and monthly and mean yearly values have been published.(3) The yearly values so derived are given in Table I.

Neither the size of the spots nor their location on the sun's disc is considered in the sunspot number. A small spot of 1000 km. diameter counts as much as a spot with a diameter of 50,000 km.

Since 1917 the Zurich observatory has published the relative number of sunspots in the central zone of the sun but these were not recorded before 1917. It is certain that a spot on the edge of the sun will have a different effect from one at the solar equator lying

directly opposite the earth and belching a stream of radiation or corpuscles directly into our atmosphere.(4)

TABLE I

Year	0	1	2	3	4	5	6	7	8	9
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
183	71.0	47.8	27.5	8.5	13.2	56.9	121.5	138.3	103.2	85.8
184	63.2	36.8	24.2	10.7	15.0	40.1	61.5	98.5	124.3	95.9
185	66.5	64.5	54.2	39.0	20.6	6.7	4.3	22.8	54.8	93.8
186	95.7	77.2	59.1	44.0	47.0	30.5	16.3	7.3	37.3	73.9
187	139.1	111.2	101.7	66.3	44.7	17.1	11.3	12.3	3.4	6.0
188	32.3	54.3	59.7	63.7	63.5	52.2	25.4	13.1	6.8	6.3
189	7.1	35.6	73.0	84.9	78.0	64.0	41.8	26.2	26.7	12.1
190	9.5	2.7	5.0	24.4	42.0	63.5	53.8	62.0	48.5	43.9
191	18.6	5.7	3.6	1.4	9.6	47.4	57.1	103.9	80.6	63.6
192	37.6	26.1	14.2	5.8	16.7	44.3	63.9	69.0	77.9	65.0
193	35.7	21.2	11.1	5.7	8.8	36.1				

Relative sunspot numbers 1830-1935.
The year is read from the first column and the top row. Thus: for 1873 the number is 66.3, for 1918 the number is 80.6.

Although a study of terrestrial magnetism and cognate subjects shows that sunspots are obviously one element in solar activity which affects the earth, it is not established that they accurately indicate fluctuations in the whole solar effect and it appears improbable that they do. The direct solar radiation received by the earth is about ten million times the energy implied in the earth's magnetic activity. The physical changes in the surface of the sun itself, the effect of

TABLE II

	0	1	2	3	4	5	6	7	8	9
192	1.948 (37.6)	1.949 (26.1)	1.927 (14.2)	1.933 (5.8)	1.944 (16.7)	1.946 (44.3)	1.938 (63.9)	1.943 (69.0)	1.938 (77.9)	1.933 (65.0)
193	1.940 (35.7)	1.946 (21.2)	1.941 (11.1)	1.941 (5.7)						

Revised values by C. G. Abbot of the solar constant in gm-cal/cm²/min compared with sunspots from 1920 to 1933.

flocculi and prominences are not considered. Dr. C. G. Abbot, with his colleagues, has determined with all possible accuracy the solar constant,(3) that is, the heat received by the earth on unit area at the top of the atmosphere. His "preferred solar constants",(5) based on ten-day mean values collected and adjusted from observations at several stations, are summarized and the mean yearly values given in Table II, and compared with sunspots in Fig. 1. An inspection of

the data shows that there is no direct connection during the period 1920-1933 between Abbot's figures for the heat received by the earth and sunspots. One might expect a closer connection between variations in the earth's magnetic field and weather than between sunspots and weather, for the changes in the earth's magnetic field are the accumulated and integrated effect of the solar activity on the upper atmosphere. The activity of the earth's magnetic field is, however, closely correlated with sunspot number, so that no startling improvement in the connection with meteorological data may be expected if the magnetic activity is substituted for the sunspot number.

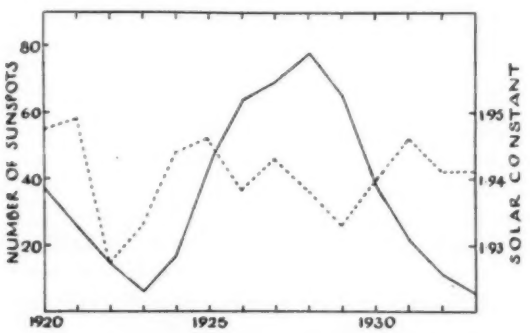

Fig. 1. Variation of sunspots and solar constant from 1920 to 1933.
No. of sunspots ———. Solar constant - - - - -.

The fluctuations in the number of sunspots are seen from Table I to have varied considerably during the past century both in amplitude and period. Thus a maximum appeared in 1830 and again in 1837 while thirteen years elapsed between the maxima of 1870 and 1883. The relative sunspot numbers in these last mentioned years of maximum sunspot activity were 139.1 and 63.7. H. Kimura(6) attempted in 1911 to forecast sunspot numbers for future years by analyzing the sunspot curve from 1750-1911 and continuing the component curves into the future (Fig. 2). The sunspot curve from 1750-1911 was analyzed into 29 sine terms, but the continuation of the resulting sine series has disagreed with the observed values since

1912. Udny Yule has also made a careful statistical study of sunspots and has arrived at the conclusion that their variations are analogous to those of disturbed periodic motion. An example of this would be a pendulum subjected to random impulses or a clock with a variable rate. Such a movement Yule points out cannot be predicted. If it is a practical impossibility to determine accurately the sunspot activity in advance, it is useless to attempt foretelling the variation in terrestrial phenomena which is claimed to accompany changes in sunspot numbers.

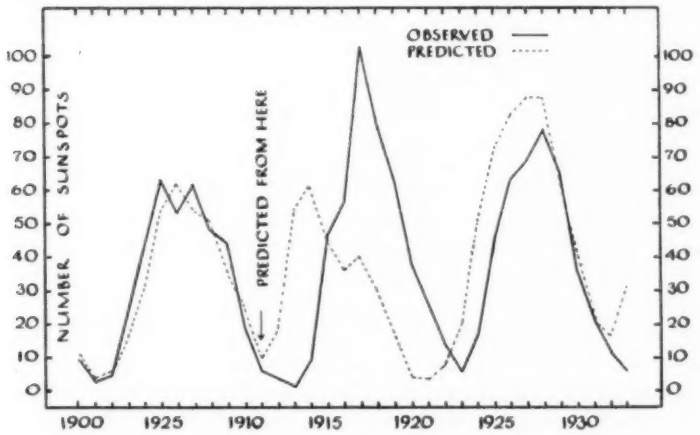

Fig. 2. Sunspot numbers predicted in 1912 by Kimura based on harmonic analysis of all previous sunspot data, and sunsposts actually observed.

Ultra-violet Radiation and Sunspots

The intensity of ultra-violet radiation has been measured at Mount Wilson Observatory since 1924.(3) The ratio of ultra-violet $\lambda = 0.32\mu$ to green $\lambda = 0.50\mu$ in June, 1934, being considered unity. The accompanying Table III gives the intensity of ultra-violet determined in this unit. The value for 1924 is based on only five months' observations and in 1925 on nine months'.

If we compare these values of ultra-violet light intensity with those of relative sunspot numbers for the same years we find there

is little similarity, the year of maximum sunspots is 1928 and of maximum intensity of ultra-violet light is 1925. In 1932 the number of sunspots was double that in 1933 but the average intensity of ultra-violet light was less. The absence of correlation between the intensity of the ultra-violet light and sunspots is shown equally clearly when the records from day to day are examined.

TABLE III

Year	0	1	2	3	4	5	6	7	8	9
192					1.07 (16.7)	1.38 (44.3)	1.37 (63.9)	1.35 (69.0)	1.23 (77.8)	1.13 (65.0)
193	1.22 (35.7)	1.07 (21.2)	0.96 (11.1)	1.03 (5.7)						

Intensity of ultra-violet light 1924-1933 at Mount Wilson Observatory compared with yearly sunspot numbers (in brackets).

The work of Rose, Henderson(7) and others has established that ultra-violet light is the principal ionizing agent in the atmosphere above 100 km. When the sun's rays were cut off during the total solar eclipse of Aug. 31, 1932, the ionization in the Kennelly-Heaviside layer fluctuated as predicted on this basis. The average number of positive ions at various levels according to Hulbert(8) is given in Table IV, for lat. 40. Above 60 km. the ionization is assumed to be caused by ultra-violet light, below by cosmic radiation and is independent of latitude and solar activity. Hulbert states the values above 60 km. should be increased or decreased 25% to refer to epochs of max. and min. solar activity. During magnetic storms the ionization increases, being probably double the tabular values.

TABLE IV

Alt. Km.	100	90	80	50	40	30	20	10	0
Ions/cm.	1.2×10^3	5.4×10^3	1.6×10^4	3.5×10^5	2.9×10^5	2.2×10^5	1.9×10^5	1.6×10^5	18×10^2

Number of singly charged positive ions (n_+) per cm^3 assuming atmosphere at each point is approximately neutral (according to Hulbert). We have the relation $n_+ = n_- + e$, where n_- = number of singly charged negative ions and e number of electrons. Values of n_+ for levels from 80 km. to 100 km. are for mean conditions at noon at 40° latitude.

Below 80 km. ultra-violet is not effective as an ionizing agent on account of its absorption higher up and the ions produced at higher levels cannot diffuse downward owing to their rapid recombination.

Recent researches by Kirby and Judson(9) indicate the prob-

ability that the Kennelly-Heaviside layer is composed largely of heavy ions with small mobility which could not migrate rapidly. The number of ions found at all levels reached by sounding balloons may be accounted for by cosmic radiation.(10) Furthermore, condensation for the formation of cloud droplets is much easier on hygroscopic particles, of which there is an abundance in the air, rather than on electrons. As Sir Napier Shaw states,(11) "So far from there being any risk of supersaturation in the atmosphere in consequence of an unsatisfied need for nuclei, it would appear probable that the difficulty to be anticipated is that the abundance and hygroscopic nature of the nuclei make the formation of fogs and clouds unconformable with Dalton's Law". In other words, considering the number of nuclei present in the atmosphere more clouds could be expected than are actually observed. It is not an increase in the number of nuclei present that is necessary for the formation of clouds but an increase in the amount of water vapour at these levels.

Atmospheric Electric Phenomena and Sunspots

If the number of ions at the earth's surface fluctuated with sunspots, these variations would be immediately indicated in the conductivity and potential gradient observations, records of the latter being available for many years. Dr. Kahler(12) states that the long and carefully kept records of atmospheric electric potential at Potsdam give no support to a connection with sunspot data, and according to C. Chree(13) the data for Kew and Potsdam are suggestive of either no direct sunspot influence or of a comparatively trifling influence liable to be masked by weather. The late Dr. L. A. Bauer,(14) after a very careful study of all conductivity records, found that nothing definite could be stated regarding sunspot influence, owing to the meagreness of available data. Thus it seems established that there is absolutely no basis for the suggestion recently made that ions and electrons migrate downward into the troposphere and by their variation in number exert an influence on the weather.

Canadian Weather and Sunspots

The meteorological data from a number of Canadian stations will now be examined to discover if any effect ascribable to sunspots

occurs in their records. In view of the possibility that the effect of sunspots might vary with the distance of the station from the ocean, some stations have been selected with extreme maritime exposure, such as Southwest Point on Anticosti Island and St. John's Newfoundland, and others with extreme continentality, such as Winnipeg, Edmonton and Calgary. To avoid uncontrollable effects due to the shifting of a station only records obtained over a long period of years at one place were employed and in general the choice of stations was restricted to those whose data appear in "World Weather", an invaluable compendium of meteorological statistics published by the Smithsonian Institution and easily obtainable. The data for the Canadian section of this publication was supplied by the Meteorological Service of Canada. This source permits ready reference and checking of results by anyone who wishes to investigate long-period fluctuations in weather.

Although the method of correlation coefficients affords an excellent index of the closeness of the connection between fluctuations in the annual number of sunspots and the annual temperature at any station, it is not as direct as the simple method of analysis which will be here employed. To explain this method, let us determine the connection between sunspots and temperature at a given station. The mean annual values of the temperature for an eleven year period centred about the year of maximum sunspots were placed in a row so that temperatures for five years of increasing sunspot values lie to the left of the year of sunspot maximum values and the temperatures of five years of decreasing sunspot values lie to the right. Data for eleven years of the next sunspot period are placed in another row just below the first row and the tabulation carried on for all the period that meteorological data are available. If the data are available for five years or less of a cycle, this fraction of a cycle was not included in the computation. When the columns are added and meaned, the result shows at once if the temperature goes through a regular fluctuation paralleling the variations in the sunspots. If sunspots do affect temperature but with a lag of one or two years this would be shown by the temperature maximum being displaced the same period to the right of the sunspot maximum.

As an example of this elementary analysis the annual values of temperature at Calgary for the past four sunspot cycles are arranged

in Table V, as indicated in the previous paragraph, to determine the average temperature fluctuation during a sunspot cycle.

The temperatures at Calgary are seen to fluctuate at random during the sunspot cycle and the figures in the Table do not support the statement(1) issued by the Department of Interior at Ottawa that Calgary shows four degrees higher temperature at maximum than at minimum sunspots when all available data are considered. The fact that the mean annual temperature in 1928, the year of last sunspot maximum, was exactly four degrees (Fahr.) *higher* than the mean temperature of 1933, the year of last sunspot minimum, may have been the basis for the statement referred to. However, in two of the three preceding sunspot cycles the temperature for the year of sunspot maximum was considerably *lower* than for the year of sunspot minimum.

TABLE V

	Decreasing Sunspots							Increasing Sunspots				
	−5	−4	−3	−2	−1	0	Year sunspot max.	+1	+2	+3	+4	+5
	°F	°F	°F	°F	°F	°F		°F	°F	°F	°F	°F
	40.9	38.6	39.5	41.0	35.7	41.4	1928	38.5	40.1	41.7	37.6	37.4
	39.4	40.1	40.5	41.8	37.4	37.9	1917	41.5	39.5	38.9	39.7	39.0
	38.6	39.2	36.9	37.6	36.9	39.0	1905	39.3	36.7	40.7	36.0	40.4
	36.7	40.5	37.0	38.8	38.1	35.3	1893	38.8	37.2	35.9	36.9	37.8
Mean	38.9	39.6	38.5	39.8	37.0	38.4		39.5	38.4	39.3	37.6	38.6

Temperature at Calgary, Alberta, during the past four sunspot cycles, arranged to determine their interrelation. Mean annual temperatures are given for one, two, etc., years before and after years of sunspot maximum.

The mean temperature at Calgary for the four years around sunspot minimum is 38.7°F. and for the three years around sunspot maximum is 38.3°F., based on the temperatures observed from 1888 to 1933 inclusive. The individual cycles differ widely from one another, thus the temperature during 1893, a year of maximum sunspots, was the lowest on record, while 1928, also a year of maximum sunspots, was within 0.4°F. of the hottest year on record. (Fig. 3). We are now at the beginning of a sunspot cycle but he would be a bold forecaster who would venture a forecast of temperature after considering the data of the last four cycles.

The temperature fluctuations during the sunspot cycle are shown in Table VI for nine stations in Canada where long records have been obtained.

The mean of the annual temperatures of all the stations ranges from 40.5°F. on the second year before to 39.4°F. on the second year after sunspot maximum. If the prairie stations only are considered, the minimum temperature occurs the year before sunspot maximum. The temperature appears to be slightly lower about years of sunspot maximum, the average temperature for the three years centred about sunspot maximum being 1.0°F. lower for the prairie provinces and 0.6°F. when all stations are included than the four years about sunspot minimum. The individual yearly values, however, do not go through a definite cycle and it is an open question if any parallelism exists between the sunspot and the temperature variations.

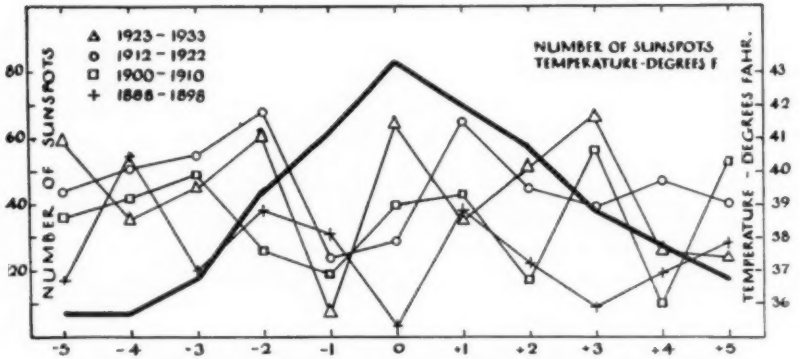

Fig. 3. Variation of temperature at Calgary during four sunspot cycles compared with sunspot variation. The zero year is the year of maximum sunspots, and data for five succeeding and preceding years are given.

Sunspots, heavy line; temperature, light lines.

Fluctuations in the number of sunspots apparently affect to a measurable degree the temperature of a few places in the tropics, like Samoa, where disturbing influences are small and the annual temperature has a very small range. Similar sunspot influences are probably exerted in temperate latitudes but other disturbing forces are so large that the sunspot effect cannot be detected in the few cycles of meteorological records now available. Thus, as a parallel, the moon affects(15) the daily atmospheric pressure at Toronto, but

it requires at least a thousand days to determine approximately the amount and four thousand days for an accurate measurement of the lunar tidal cycles. If the sunspot effect were of the same relative importance to temperature as the moon to pressure, it would require a thousand cycles, or over ten thousand years of observations, to determine its magnitude.

TABLE VI

Years Before or After Sunspot Maximum

Station	Period	−5	−4	−3	−2	−1	0	−1	−2	−3	−4	−5
		°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
Victoria	1891-1933	50.4	49.7	50.6	50.3	49.0	49.1	49.6	49.3	49.6	48.7	49.2
Kamloops	1900-1933	47.5	47.1	47.8	48.4	45.8	47.3	47.8	46.3	47.9	46.6	43.9
Edmonton	1888-1933	37.6	38.6	36.7	38.2	35.1	36.9	37.8	36.6	36.9	35.9	36.5
Prince Albert	1888-1933	33.1	33.9	32.8	33.4	31.6	32.8	33.6	32.9	34.8	33.2	33.9
Qu'Appelle	1888-1933	34.9	36.2	35.6	35.8	33.1	35.2	36.0	34.5	36.6	35.0	35.6
Winnipeg	1878-1933	36.6	35.3	35.4	35.9	34.2	33.6	35.3	34.7	36.6	35.1	35.8
Toronto	1843-1933	44.8	44.7	45.0	45.4	44.6	44.4	45.0	44.8	45.2	45.8	45.1
Montreal	1878-1933	42.4	42.7	42.2	43.2	42.0	41.0	42.6	42.2	43.0	43.2	42.8
Southwest Point	1882-1933	34.8	36.3	34.5	34.2	34.6	34.0	33.4	34.7	35.2	35.4	36.5
Mean		40.1	40.4	39.9	40.5	38.7	39.2	40.1	39.4	40.5	39.6	39.8
Mean of Prairie Stations		36.2	36.7	35.8	36.5	34.2	35.4	36.4	35.5	36.8	35.4	36.2

Temperature fluctuations at nine stations during the sunspot cycle. The mean value includes the Calgary record given previously. The Prairie Stations comprise Calgary, Edmonton, Prince Albert, Qu'Appelle and Winnipeg.

To be practically useful the individual yearly or seasonal temperature values must be foretold and it is far from sufficient to indicate a slight general trend if, as in the case of sunspot effect for

TABLE VII

		−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
Station		°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F;
Montreal	Max.	45.4	44.6	43.0	44.8	43.8	43.3	43.3	44.6	46.1	45.0	44.1
	Min.	40.1	41.1	41.0	40.7	39.4	39.5	41.5	39.4	41.3	41.0	40.1
Toronto	Max.	47.3	47.7	46.0	46.8	46.8	46.7	46.7	48.3	49.4	49.8	47.5
	Min.	42.4	42.2	42.8	43.3	42.6	41.5	43.4	40.8	42.3	43.8	40.6
Winnipeg	Max.	40.4	36.4	37.9	38.4	36.0	38.9	37.2	37.9	41.5	38.4	38.7
	Min.	32.1	32.3	31.4	34.1	32.8	29.0	30.9	31.6	33.4	31.0	32.1
Calgary	Max.	40.9	40.5	40.5	41.8	38.1	41.4	41.5	40.1	41.7	39.7	40.4
	Min.	36.7	38.6	36.9	37.6	35.7	35.3	38.5	36.7	35.9	36.0	37.4

Temperature of warmest and coldest year which has occurred at four typical stations during each year of the sunspot cycle based on all available records. Thus the temperature at Toronto during the year of sunspot maximum has varied between 46.7° F. and 41.5° F.

the prairie provinces, it is so small that it cannot be determined with accuracy. Thus if for any station the departures from the yearly mean during the cycle are ± 2.5° and the sunspot effect is

TABLE VIII

		−5 in.	−4 in.	−3 in.	−2 in.	−1 in.	0 in.	+1 in.	+2 in.	+3 in.	+4 in.	+5 in.
Montreal	Max.	53.0	48.0	46.0	44.7	49.1	44.7	50.0	44.6	42.6	47.7	45.0
	Min.	42.3	38.3	32.7	29.2	37.7	37.9	31.0	35.4	38.2	31.0	36.8
Toronto	Max.	50.2	39.4	40.6	38.6	39.8	46.2	37.0	35.4	35.3	40.9	33.6
	Min.	26.2	28.1	27.2	26.9	24.8	26.8	28.6	25.7	27.3	24.3	24.0
Winnipeg	Max.	22.8	23.9	24.9	20.2	24.2	23.9	22.5	25.1	26.3	23.1	27.2
	Min.	15.7	15.0	16.1	16.9	19.9	13.8	14.3	16.9	16.9	17.6	18.9
Calgary	Max.	23.9	24.3	34.6	24.4	29.8	16.6	16.2	15.1	18.3	21.0	16.2
	Min.	17.5	11.6	15.5	10.4	7.9	11.0	9.1	12.0	11.8	11.2	10.7

Precipitation during driest and wettest year which has occurred at four typical stations during each year of sunspot cycle. Thus at Winnipeg the precipitation during the year of sunspot maximum has varied from 23.9 in. to 15.8 in.

± 0.3° a forecast based on sunspot influence has no meaning. The range of temperature and precipitation for each year of the sunspot cycle is given in Tables VII and VIII for a number of stations.

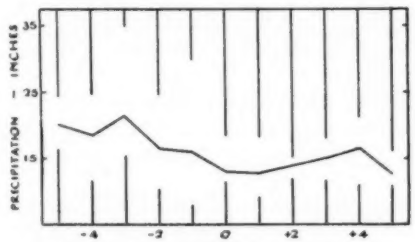

Fig. 4. Mean variation of precipitation at Calgary during sunspot cycle. The highest and lowest annual values for each year of the cycle are given by the limits of the ordinate. This shows a wide scatter of values for each year of the cycle.

Precipitation and Sunspots

Precipitation at typically located Canadian stations was investigated by the same method as employed for temperature, to discover the effect, if any, exerted by changes in the number of sunspots.

(Fig. 4). The total annual precipitation was considered, employing the usual assumption that ten inches of snowfall is the equivalent of one inch of rain.

TABLE IX

		−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
St. Johns, Nfld.	1878–1920	53.62	47.24	48.52	52.56	57.64	56.45	58.37	60.67	51.30	58.46	58.07
S-West Pt.	1882–1920	31.36	29.83	32.95	31.70	27.21	28.00	31.30	34.99	34.44	31.24	33.54
Montreal	1878–1933	45.09	43.96	40.90	35.76	41.93	41.00	41.34	40.41	40.70	39.44	40.81
Toronto	1843–1933	36.87	31.79	33.18	33.35	33.30	34.48	33.10	31.09	30.67	32.21	29.37
Winnipeg	1878–1933	18.50	18.30	20.78	18.54	22.13	19.62	18.60	20.76	20.50	20.56	22.18
Qu'Appelle	1888–1933	19.66	18.68	21.20	19.27	22.69	17.42	15.08	16.22	17.68	21.73	19.73
Pr. Albert	1888–1933	16.86	15.00	16.93	14.64	16.41	12.00	13.14	15.96	17.86	20.62	13.91
Edmonton	1888–1933	21.34	18.50	21.35	18.16	18.84	15.96	17.12	15.03	17.54	14.54	15.34
Calgary	1888–1933	20.07	18.80	21.45	18.97	15.89	13.36	12.88	14.14	15.14	16.57	12.98
Kamloops	1900–1933	11.70	10.19	11.22	10.93	12.86	8.73	10.67	8.67	7.62	8.06	8.47
Victoria	1891–1933	27.36	25.88	24.41	28.74	30.40	31.17	29.08	25.61	33.41	34.20	28.42
Mean all stations		27.49	25.29	26.63	25.69	27.27	25.29	25.51	25.78	26.08	27.06	25.71
Departures		+1.34	−0.86	+0.48	−0.46	+1.12	−0.86	−0.64	−0.37	−0.07	+0.91	−0.44
Prairie Stations		19.29	17.86	20.34	17.72	19.19	15.67	15.36	16.42	17.74	18.80	16.83
Departures		+1.54	+0.11	+2.59	−0.03	+1.44	−2.08	−2.39	−1.33	−0.01	+1.05	−0.92
Maritime Stations		37.44	34.32	35.29	37.67	38.42	38.54	39.58	40.42	39.72	41.30	40.01
Departures		−0.99	−4.11	−3.14	−0.76	−0.01	0.11	1.15	1.99	1.29	2.87	1.58

Mean annual precipitation for years centered about sunspot maximum. Prairie stations include Winnipeg, Qu'Appelle, Prince Albert, Edmonton and Calgary. Maritime stations include St. Johns, Nfd., South West Point, (Anticosti) and Victoria, B.C.

When the precipitation records from all stations are grouped together the fluctuations from year to year during the sunspot cycle are comparatively small and show no regularity, the precipitation for the year before sunspot maximum is 1.07 inch above the mean while the precipitation for the year of sunspot maximum is 0.95 inches below the mean. (Fig. 5). Stations that are maritime and those on the prairies, considered separately, differ in their precipitation, the prairie stations having received above normal precipitation during years of increasing sunspots while the maritime stations at the same part of the cycle received below normal precipitation. When the yearly amounts of precipitation are considered it is seen that the scatter of the values in any 11-year period is so great that a forecast based on a cyclical variation would be futile.

Sunspots and Cloudiness

Although cloudiness is not measured as accurately as precipitation and temperature, being visually estimated twice a day at 8 a.m. E.S.T., and 8 p.m. E.S.T. in tenths of sky covered by clouds, the summarized figures for four stations are given in Table X in order

TABLE X

Station	Period	−5	−4	−3	−2	−1	0	1	2	3	4	5
Halifax	1878–1933	6.2	6.3	6.2	6.3	6.3	6.4	6.4	6.3	6.2	6.2	6.6
Victoria	1900–1933	6.0	5.9	6.1	6.2	6.0	5.9	5.8	5.5	5.9	6.0	6.0
Winnipeg	1900–1933	4.7	4.7	5.3	5.4	5.2	5.1	5.4	5.6	4.8	5.0	5.0
Toronto	1878–1933	5.7	5.8	5.8	5.9	5.9	5.9	5.9	5.7	5.7	5.7	5.6
Mean Maritime Stations		6.1	6.1	6.2	6.2	6.2	6.2	6.1	5.9	6.0	6.1	6.3
Mean Departures		0.0	0.0	0.1	0.1	0.1	0.1	0.0	−0.2	−0.1	0.0	0.2
Mean Continental Stations		5.2	5.2	5.6	5.6	5.6	5.5	5.6	5.3	5.2	5.4	5.4
Mean Departures		−0.2	−0.2	0.2	0.2	0.2	0.1	0.2	−0.1	−0.2	0.0	0.0

Cloudiness expressed in tenths of sky cloud-covered, based on observations at 8 a.m. and 8 p.m. E.S.T. Victoria and Halifax are considered maritime and Toronto and Winnipeg continental stations.

to see if any indication of a period resembling sunspots is present. It has been claimed that the ionized state of the upper air exerts an

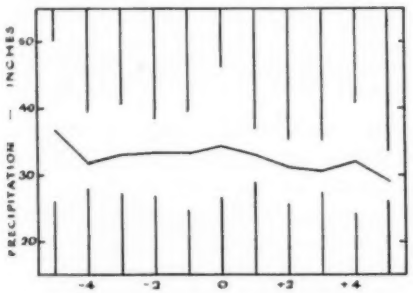

Fig. 5. Variation of precipitation at Toronto during sunspot cycle. A long record from 1843 to 1933 is available and a wide range for each year shown by the length of the ordinate left blank has occurred.

influence on the amount of cloud in the troposphere and through cloudiness, affects rainfall, temperature and all other elements.

The variation in cloudiness from year to year is small and irregular, the values around sunspot maximum for the more continental stations, Winnipeg and Toronto, being slightly greater than at sunspot minimum. The cloudiness at Winnipeg varies more than at other stations and this result arises largely from low values for the fourth and fifth years before the year of sunspot maximum.

Thunderstorm Frequency and Sunspots

Many investigators have claimed that there is a close correlation between sunspots and thunderstorms in various regions of the earth, but unfortunately, even for the same region, some have claimed that thunderstorms are more frequent while sunspots are few and others claim that thunderstorm frequency parallels sunspot numbers. Thus A. Hess and Emden(16) find that thunderstorms in Switzerland and Bavaria vary inversely with sunspots. On the other hand A. Gockel(17) finds a direct relation between them for Spain and Bavaria, and A. Steen a direct relationship for Denmark and Scandinavia. The Director of the British Meteorological Office in his latest annual report states that in high northern and in tropical latitudes thunderstorms are more frequent when sunspots are more numerous but that this did not hold true in temperate latitudes. It is of interest to investigate if any correlation between thunderstorms and sunspots exists in the long and carefully kept record of days on which thunderstorms have occurred at Toronto.

In order that the data be kept uniform throughout the whole period, the old definition of thunderstorm has been retained, namely, the observance in the same storm of two of thunder, lightning and rain. The statistics for thunderstorms at Toronto are given in full in Table XI, obtained from the monthly reports of the Meteorological Office except for a few earlier years which were secured from the manuscript of the daily weather record kept at Toronto.

When the thunderstorm data are arranged in cycles to determine the connection with sunspots, the parallelism as seen in Table XII, is very poor.

There is a slightly larger number of thunderstorms in three years centering about sunspot maximum but this may be only a random chance as the pronounced minimum of thunderstorm days occurs on the second year before sunspot maximum. (Fig. 6). The indi-

vidual cycles show great differences. Thus 1905 was a year of sunspot maximum but also the absolute annual minimum of thunderstorms, while 1883 was a year of maximum sunspots but also had the greatest number of thunderstorms during the cycle 1878-1888.

The recently published statement of the Department of Interior, Ottawa, that thunderstorms were 30% more numerous at Toronto in years of sunspot minimum, is not verified when records are taken over a number of cycles.

TABLE XI

Year	0	1	2	3	4	5	6	7	8	9
184	21	26	19	23	20	27	25	32	20	
185				26	30	27	25	26	22	30
186	34	27	30	29	28	22	27	22	24	31
187	34	26	28	21	22		19	33	29	35
188	46	25	28	35		19	26	21	23	24
189	21	18	36	35	36	22	23	19	31	29
190	34	25	26	19	26	15	21	23	27	21
191	21	34	26	22	27	26	26	27	31	20
192	25	35	31	25	32	28	21	21	27	29
193	24	24	28	25						

Annual number of thunderstorms observed at Toronto 1840-1933.

The experience of the United States may be considered regarding the greater danger of forest fires expected by the Department of Interior, Ottawa, with increasing thunderstorms. In the United States uniform records of thunder days, that is, days on which thunder was heard regardless of the occurrence of rain or lightning,

TABLE XII

	−5	−4	−3	−2	−1	Sunspot Max.	1	2	3	4	5
Mean	27.1	25.6	28.1	21.8	28.8	28.4	28.3	23.7	25.0	24.9	25.5
Departures	1.0	−0.5	2.0	−4.3	2.7	2.3	2.2	−2.4	−1.1	−1.2	−0.6

Fluctuations in the number of thunderstorms observed at Toronto during the average sunspot cycle based on observations 1840-1933.

are available from 1904-1913. These records of thunder days show extremely close agreement from year to year with the total precipitation, years of over-the-normal precipitation being years with most frequent thunderstorms. Years of great forest fires are invariably dry years and thus fortunately of comparatively few thunderstorms.

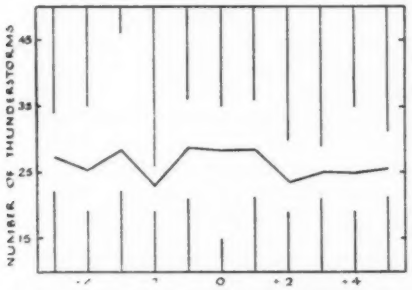

Fig. 6. Variation of thunderstorms during sunspot cycle at Toronto, 1840 to 1933. The great range of thunderstorms which has occurred during each year of the cycle is shown by the length of the ordinate left blank.

Summary

1. Variations in the period and amplitude of sunspot fluctuations are so great that the number of sunspots present a year or so in advance cannot be accurately forecast. Hence seasonal weather forecasts based on sunspot numbers are unreliable.

2. Observations do not confirm the recently proposed theory that variations in the ionization of the Kennelly-Heaviside layer and higher strata of the atmosphere (above 90 km.) are correlated with the electric state in the troposphere.

3. Precipitation, temperature and cloudiness at stations along the southern border of Canada and thunderstorms at Toronto may be affected by variations in sunspots, but records extending from 30 to 80 years at these stations are not sufficiently long to show it. Temperatures over the prairies are possibly slightly lower during years of sunspot maximum, but yearly values in any cycle show a random scatter about the mean.

4. The temperature and rainfall departure at any station for a particular year of the sunspot cycle varies so irregularly from the mean from one cycle to another that it is without value to attempt to use the sunspot variation curve for forecasting weather at stations in Canada.

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SUNSPOTS AND ABUNDANCE OF ANIMALS

By D. A. MacLulich

THE possible correlation of sunspot cycles and fluctuations in numbers of animals has been carefully considered in connection with a study of the varying hare or snowshoe rabbit, *Lepus americanus*, being carried out under the auspices of the Department of Biology of the University of Toronto and the Royal Ontario Museum of Zoology. As the results are somewhat at variance with the general opinions of those who have written on this subject the literature is reviewed and new arguments and conclusions presented. This paper is one section of the report on the above-mentioned investigation of the varying hare, the other parts being in process of preparation.

Review of Literature on Sunspots and Animal Abundance

In 1878 Swinton, in England, submitted inconclusive evidence that outbreaks of grasshoppers tend to occur at times of a minimum number of sunspots.

Ljungman (1880) compiled a record of the condition of the "genuine sea-herring" fishery on the coast of Bohus län (Swed.), finding good fisheries every 11.1 years. He claimed that there was a corresponding 11.1 year major period in sunspot abundance. In a footnote he admits, in regard to a correlation of governmental fisheries revenue "during the present and the last century with Wolff's relative figures, I have not been able to find any very striking coincidence between the occurrence of solar spots and good fisheries."

Simroth (1908) pointed out that the invasions of Europe by the Siberian race of the Nutcracker (a bird) in 1844, 1864, 1885, 1896 and 1907 were correlated with the sunspot cycle.

Soon after Hewitt's book (1921) came out, DeLury wrote pointing out a correspondence between the fur records and the sunspot cycle. DeLury (1923) worked over some migration records from Montdidier in France from the year 1784 to 1869 and found the cuckoo arrived nine days later in years of sunspot maximum than in years with a minimum number of sunspots, the lark three days later and the swallow only one day.

It might be mentioned that the present writer has just re-investigated these records of bird arrivals, the migration dates being abstracted from DeLury's tables. Between the years 1813 and 1839 the cuckoo data are incomplete; there are figures for only eight years. This would suggest that the observers were not so thorough in their watching for the birds, and that the figures are probably not so reliable as for the other 59 years. Using only the periods of regular observation, the difference in time of arrival is reduced from nine days to three and three-quarter days, while the correlation coefficients of sunspot number and date of migration of neither the cuckoo nor the lark are large enough to be significant.

The next year Elton (1924) in a comprehensive paper on cycles of lemmings, rabbits and several other animals and birds came to the conclusion that the periodic fluctuations in the numbers of these animals are due to the weather, which in turn is correlated with the sunspot cycle. He decided that the abundance of varying hares, as recorded by the Hudson's Bay Company fur returns, was related to the 11.2 year sunspot cycle. The discrepancies were explained by the changes in mean earth temperature, which showed cooling effects after major volcanic eruptions, due to the dust emitted into the atmosphere. He went on to say: "If we allow for the irregularity in 1905, the rabbit period agrees very well with that of the sunspots; *i.e.*, omitting the one in 1905, the average period for rabbits between 1845 and 1914 is 11.5. But the 1914 one should have been in 1912, and this brings the average to 11.1, which is about that of the sunspots (11.2)." He found no known cause for the short 3½ year cycles of lemmings and mice. The lack of complete simultaneity in animal fluctuations over the whole country was inferred to be due to the sunspot variation causing a cyclic shifting of the isoclimatic lines, with the result that rainfall increased at some places while it decreased at others. Julian Huxley (1927) in a popular article stated this more decidedly and also related the lemming cycles to a component of the sunspot cycle equal in length to one third of the main cycle.

DeLury (1930) pointed out correlations of grasshopper and grouse maxima with sunspot minima; Criddle (1932) expanded the argument with much additional information on grasshoppers, but the correlation shown by the graphs is not convincing to the present writer.

From a study of outbreaks of certain forest insects Eidmann (1931) has concluded that they are correlated with sunspot maxima.

Leopold in 1931 wrote as follows of grouse cycles: "There is no significant synchronism between Britain and America, the periods being different. This would seem to refute the theory that cycles are basically due to fluctuations in solar radiations or sunspots, unless such fluctuations operate through entirely different biological channels in America and Britain respectively."

At the Matamek Conference on Biological Cycles as reported by Huntington (1932) and Elton (1933b) the sunspot cycle theory received considerable attention but not unanimous acceptance. DeLury suggested (to quote Elton 1933b): "It is possible that the 9.7 year cycle in animal life is due to a climate cycle of short length caused by a blending of the 11.2-year sunspot cycle and the 8.85 lunar cycle in tides. Oceanic and inland reactions to the astronomic factors of opposite phase, were found, and illustrated by charts, resulting in half astronomical periods in some intermediate localities such as Anticosti."

Chapman (1933) said ". . . the whole matter of sunspot cycles and its effect upon biological phenomena rests upon a rather uncertain foundation."

A note on sunspots and squirrel emigrations was written by Anthony in 1934, in which he said: "A very interesting and, it might be said, troublesome coincidence exists between the periods of sunspot maxima and minima and the periods of plant growth . . . and the spectacular fluctuations of animal abundance. This coincidence is troublesome because it hints at too much to be overlooked, and yet the theories which attempt to show causal relations are by no means conclusive."

Wing (1934a, b) showed a relation between migration times of various birds and solar cycles and developed the idea further with more data in 1935. Quoting (Wing 1935): "The cycles are interconnected and composed of several elements but different species may respond to different components of solar activity, hence cycles may differ in amplitude, length, phase and latitude." He laid particular emphasis upon the Brückner cycle of 22.5 years, relating it to both migration dates and Hudson's Bay Company fur returns. In this connection it may be pointed out that the Brückner cycle is 35 years long rather than 22.5 years (Brückner 1890, as sum-

marized in Hanns' *Handbuch der Klimatologie*, 1932). Leopold in a foreword to Wing's article wrote: "Apparently solar radiation is a common and cosmic denominator underlying the population behaviour of many species and conditioning their mechanism for population maintenance."

The Available Data on Fur Returns

Before using the fur returns as indices of abundance it is necessary to review critically the literature and discuss some points about the methods of using them. The only published tables of figures of fur returns of the Hudson's Bay Company were obtained by Henry Poland (1892), and include those between the years 1752 and 1890. He made mention of the fact that hares are abundant in some years but not in others, but failed to note the periodic nature of these fluctuations. His figures seem reliable as he was careful to state what they represented (quoted below), and in footnotes mentioned when any shipment had been delayed or lost.

MacFarlane (1905, 1908) gives Hudson's Bay Co. figures for a small number of scattered years to indicate the fluctuations in numbers of many fur-bearing animals. There must be some unexplained features about some of these figures as certain of them do not agree at all with those obtained from the Company by Poland and Seton and Hewitt.

Seton (1911) wrote: "Through the courtesy of its officials I have secured the Company's returns for the 85 years—1821-1905 inclusive", and he published graphs of the numbers of pelts with considerable discussion of the fluctuations. The graphs, except in the case of the rabbit, show points for the years 1906 to 1908 in addition to those mentioned above. The numbers of pelts agree with those of Poland's book (1892), as closely as may be read from the graphs. These plates were copied in his *Lives of Game Animals* (1925-28).

The fourth independent publication of the fur catch was by Hewitt (1921) who said: "Through the kindness of Mr. W. H. Bacon, late fur commissioner of the Hudson's Bay Company, I have been able to obtain the fur returns of that Company covering a long period of years, from 1821 to 1914." These figures were presented in the form of graphs and the cycles analytically discussed n much detail. Several corrections are necessary, but unfortunately

are not mentioned in Hewitt's book. On the rabbit graph the vertical scale of numbers is only one tenth of the values given by Poland (1892) and Seton (1911), therefore it is thought that the fur figure 15,000, for instance, should be read as 150,000. In the graph of lynx numbers the values have all been plotted over the year *after* that for which they were quoted by Poland and Seton. On this curve the figure for the year 1868 is higher than that of Poland and Seton for 1867 by 10,000, causing a one year difference in the year of peak abundance. Other writers have copied their fur figures from Seton or Hewitt.

In recent years ". . .The Hudson's Bay Company has made available for study by Mr. Charles Elton its records covering fur catches in Canada for many years past and has provided facilities in the Company's organization for the collection of statistical material bearing on cyclical fluctuations in animal life" (Huntington 1932, Elton 1933a & 1933b).

The fur returns, as published in graph form by Seton (1911, 1928), Hewitt (1921) and all who have used their figures to portray the changes in abundance of animals, are plotted over the year of sale and office return. This is proven by the fact that the figures in Poland's book (1892) agree with the values of Seton (1911) for the same years. Poland stated that the Hudson's Bay Company quantities are "those that are imported towards the end of the previous year, excepting those shipments which are delayed by the ice to the north of Hudson's Bay; these do not arrive till the year after." There is no ambiguity about this statement. Furs reported for any particular year represents the abundance of the animal at the end of the summer season of biological production *two years* previous. For example, the pelts of animals from the biological summer season of 1878, which were trapped in the winter 1878-79 were traded to the Company by the Indians, Eskimos, and white trappers in the spring and summer of 1879. These furs were graded and shipped to England that summer and autumn, and sold and recorded in the London fur sales of the winter and spring of the year 1880. Elton (1924) said: ". . . the Hudson Bay Company fur returns for any year include the catch of the winter before; in fact this is the main item, *i.e.*, a maximum of skins in 1907 means many foxes caught in the winter 1906-07, and in the spring. Such abundance will, of course, be the result of the year 1906." In the discussion above it has been shown that the 1907 catch referred

to the abundance of animals as a result of the year 1905 rather than 1906. In regard to a graph of the lynx returns for the Mackenzie River district alone, Elton's statement (1933a): "Dates refer to old *outfit* years, *i.e.*, the years of biological production and not to the year of office return or sale" is unquestionably correct, as the figures were compiled largely from trading post account books.

As Poland's book (1892) is not generally available it is worth reprinting some of the information contained in it. "These vessels make one voyage a year, either from Hudson's Bay or the North-West coast of America. The York Fort ship arrives in London in September; the Moose River ship at the end of July or beginning of August; and the Vancouver Island at the end of November or December. Many shipments are, however, now made by the great steamship lines from Montreal, the transit by steam being more expeditious. Some goods from the North-West district are sent through the West Indies, the passage by Cape Horn being only used for the bulkier and less valuable goods." The record of shipments lost or delayed was given as follows in footnotes: abbreviations; M.R. means the shipment from Moose River, E.M. the shipment from East Main River, and Y.F. that from York Fort or Factory. "1833, Y.F., M.R. not arrived this year. 1834 including Y.F., M.R. of 1833. 1936 Y.F. not arrived this year. 1837, including Y.F. of 1836. 1864, M.R., E.M. not arrived this year. 1865, including M.R., E.M. of 1864. 1873, M.R., E.M. not arrived this year. 1874, including M.R., E.M. of 1873. 1884, M.R., E.M. not arrived this year. 1885, including M.R., E.M. of 1884, no M.R., E.M. of 1885, lost at sea. 1886, part of Y.F. not imported, Cam Owens wrecked. 1887, with part of Y.F. 1886. 1890, part of Y.F. not imported."

Still quoting Poland: "The fur sales of this Company takes place at the commencement of the year; the Beaver, Musquash, and American Rabbit in January, and all other furs in March. Up to 1878 the North-West goods were sold in September; in 1880-82 they were sold in July; since that date they have been included in the March sales."

In recent years fur has been taken out quickly by the railways and steamships, although one shipload is still sent each year from Moose Factory through Hudson Strait (Dominion Bureau of Statistics, 1927). The writer does not know whether the practice of selling Canadian fur at autumn fur sales has been revived, but such recent developments would not affect the fur returns used in this paper. A number of the Company posts have been abandoned as they ceased to pay their expenses. Free traders are taking an increasing part of the fur catch and Canadian furs are being sold extensively in St. Louis, Winnipeg, Edmonton and Montreal (Dominion Bureau of Statistics).

Starting with 1920-21 the Dominion Bureau of Statistics at Ottawa has been publishing the numbers of pelts of various fur-

bearing animals "taken in Canada, years ended June 30," in the Canada Year Book, compiled from reports required of fur traders.

The Abundances of Hare and of Lynx

In fig. 1 the history of the abundance of the snowshoe hare (*Lepus americanus*) is depicted in the form of a graph. The part from 1788 to 1820 has not previously been published in graph form, and, although suggestive, it is too irregular to demonstrate much about the abundance of rabbits. The gap from 1825 to 1843 occurs in all of the source books, and the extremely high total of 285,607 skins for 1843 probably includes an accumulation from at least a part of the above gap. For the purposes of this paper a peak of abundance carries the idea that it marks the end of the period of abundance. For calculations based on the hare graph the year 1864 was therefore used as a peak year, although the figure for the previous year was slightly higher. Poland (1892) wrote: "Quantities are nevertheless subject to a certain degree to the demand. . . . The Indians, on the other hand, trap all sorts of fur-bearing animals, and refuse to do business with a collector if he will not buy all the kinds." Many rabbit skins were utilized by the Indians and at the posts for blankets and clothing and never reached the fur market. MacFarlane (1905, 1908) said: "The Hudson's Bay Company does not trade rabbit skins in the interior, but from the posts situated on the shores of Hudson Bay they annually export to England many thousands."

The fur returns for lynx, (*Lynx canadensis*), are shown in fig.2. The year 1789 is taken as a peak for calculations, as it is central in a group of three low modes. It is a generally recognized fact, borne out by the fur records, that lynx abundance is governed by that of rabbits, their staple food. Quoting MacFarlane (1905, 1908): "The yearly catch of lynxes rapidly diminishes in volume as soon as the rabbits become scarce and when the latter are comparatively rare a large proportion of the great, but now dwindling crowd of lynxes suffer privation, and some actually starve to death." Seton (1925) narrates that during the winter of 1906-07 in the Mackenzie River valley "I met with a dozen lynxes that were dying of starvation—mere walking skeletons—and in the silent woods found a dozen shrivelled corpses." None of the lynxes he examined had any rabbit in its stomach, nor much of anything else. The decrease in abundance of the rabbits is abrupt

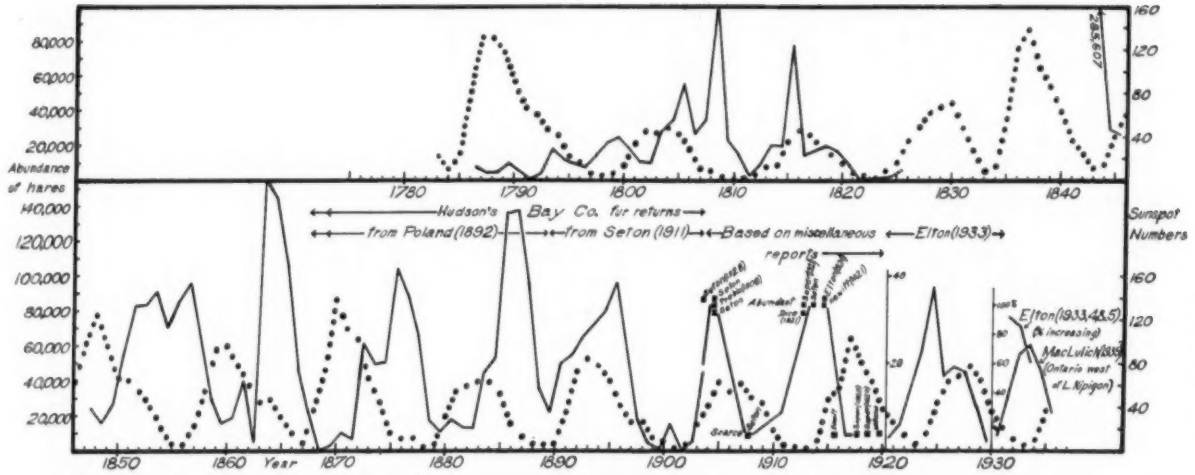

Figure 1. Abundance of varying hare (Lepus americanus) compared with sunspot numbers.

The abundance of hares in winter (solid line) plotted over end of year in which the winter began, i.e. after the season of its biological production. Sunspot numbers (dotted line) plotted over middle of each year (the marks on base line).

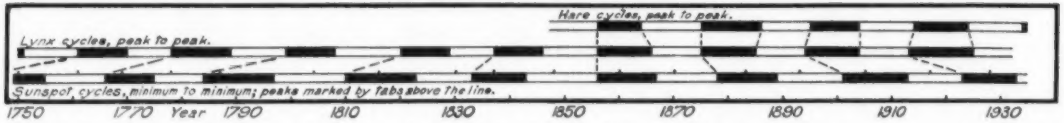
Hare cycles, peak to peak.
Lynx cycles, peak to peak.
Sunspot cycles, minimum to minimum; peaks marked by tabs above the line.
Year

Figure 3. Visual comparison of cycles of abundance of hares, lynxes and sunspots. Alternate cycles marked in black.

and rapid; they "almost disappear within one or two years". (Mac Lulich 1935). Seton (1928) suggested that the decreases in abundance of rabbits were caused by epizootic diseases and parasites, and this is the generally accepted opinion. Several of the rabbit peaks, suggested by the early inadequate fur returns, are in close agreement with the lynx peaks. Since their peaks in 1856 the average lengths of the cycles have been 9.8 years for the rabbits and 9.9 years for the lynx. The lags of the lynx peaks after the rabbit peaks were: 0, +2, 0, −1, −1, 0, −1, +1, and averaged zero. The strength of association between rabbit and lynx abundance may be measured by the coefficient of correlation. A coefficient of *one* means perfect correlation and *zero* means complete lack of correlation. If the coefficient is less than its probable error there is no correlation and if it is greater than six times its probable error there is definite correlation (Tuttle and Satterly, 1925). A positive coefficient means the two variables increase together, a negative one means one increases while the other decreases. The coefficient of correlation of the rabbit and lynx abundance is +0.55 with a probable error of only one eleventh of that value, *e.g.* ±0.05, which shows definite correlation. For this calculation the abundance of the rabbit and that of the lynx were read off the graphs of figs. 1 and 2 as scarce, intermediate or abundant, for each year from 1847 to 1934 inclusive. This simple treatment was necessary due to the varied nature of the scales of different sections of the graphs; the coefficient calculated from it compares the synchronism of the cycles.

Thus we see that over the interval from 1847 to 1934, for which the rabbit returns are most complete, the cycles correspond very closely with those for the lynx.

Animal Abundance and Sunspot Numbers

For comparison with the animal curves, the sunspot numbers have been shown on both figs. 1 and 2. These are the final relative sunspot numbers, whole disc, annual means, compiled by the I.A.U. (Eidgenössische Sternwarte, Zurich, 1934). As has been shown above, the lynx returns are more reliable than those of the hare, and extend over many more consecutive years. Hence their correlation with sunspots should be a more critical test than that of rabbits; and due to the close correspondence of lynx and hare figures over the shorter interval, any lynx-sunspot correlation

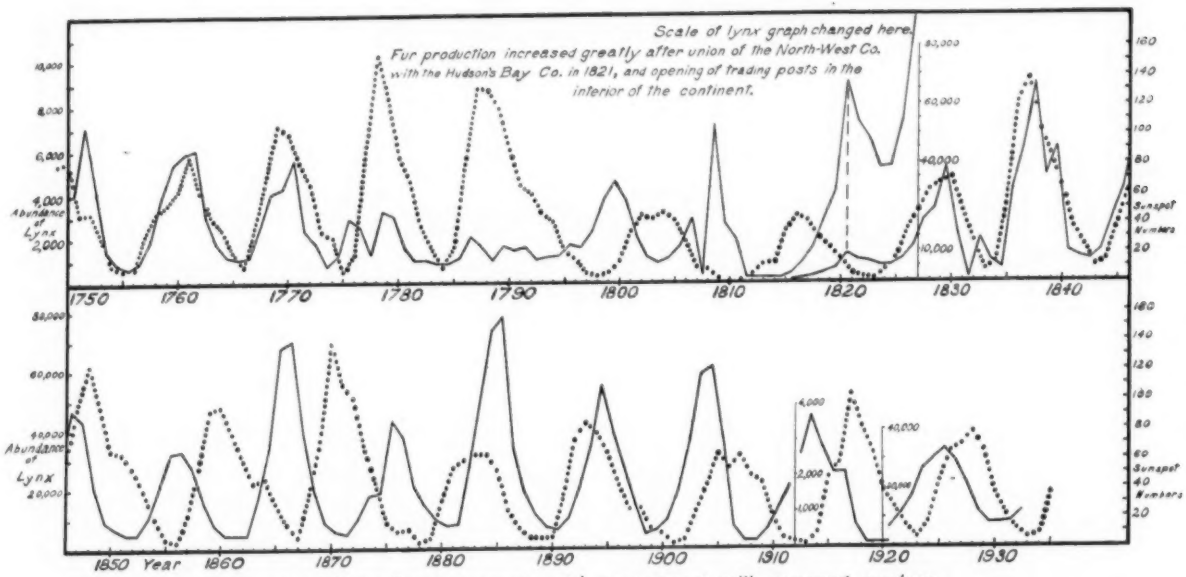

Figure 2. Abundance of lynx (Lynx canadensis) compared with sunspot numbers.

The lynx abundance in winter (solid line) plotted over end of year in which the winter began, i.e. after the season of its biological production. Sunspot numbers (dotted line) plotted over middle of each year (the marks on base line). Basis of lynx curve: 1750 to 1911 - Hudson's Bay Co. fur returns, up to 1888 from Poland (1892), to 1906 from Seton (1911) and the last 5 years from Hewitt (1921); 1912 to 1920 from Elton (1933) H.B.Co records for Mackenzie River district alone; 1920-1932 from Canada Year Books.

should hold equally for hares. The long time interval is naturally very important statistically in discussing cycles which are known to vary considerably in length.

We may now proceed to compare lynx abundance with sunspot numbers, for both of which data are available for 183 consecutive years. From the lynx peak in 1751 to that in 1925, 174 years, there were 18 cycles of lynx numbers, but only $15\frac{1}{2}$ sunspot cycles. The average lengths of the cycles were 9.7 years for the lynx and 11.1 years for the sunspots. These facts in themselves mean the two cycles cannot be correlated, but are independent. The histories of the lynx, rabbit and sunspot cycles are compared visually in fig. 3. Each history is represented by a thick horizontal line along a scale of years, with the alternate cycles marked in solid black, and the others left clear. It will be seen that the lynx and sunspot cycles get progressively farther out of step, on the average one and a half years more for each sunspot cycle. From 1750 to 1792 the lynx peaks and sunspot maxima were within two years of each other; then till 1824 the lynx peaks were close to sunspot minima; until 1850 the previous condition held; until 1877 conditions were reversed; thence to 1906 lynx peaks were within two years of sunspot maxima and recently they have been close to sunspot minima again. This is the situation that necessarily exists with two independent cyclic curves of slightly different period. The sunspot cycle is more variable than the animal cycle, ranging in length from seven to seventeen years, while the animal cycles have varied from eight to twelve years in length. The lags of the lynx peaks after the nearest sunspot peaks average $-1/5$ of a year; the lags after the nearest sunspot minima average $-1/6$ of a year, almost the same amount. Without shifting the curves into phase, as there is no lag shown above, the coefficient of correlation is $+0.04$ with a standard deviation of ± 0.05. In this calculation the lynx abundance was all read off the graph by the one scale of figures running to 80,000 skins, and the actual sunspot numbers were used. This again shows no correlation between sunspots and lynx numbers.

The fact that lynx abundance is not correlated with sunspot numbers is strong evidence, amounting to proof, that rabbit numbers are not related to sunspots. Between 1856 and 1933 there have been eight rabbit cycles, but one less sunspot cycle; the average length of the rabbit cycle was 9.6 years, but the sun-

spot cycle averaged 11.0 years. Therefore the rabbit fluctuations is not related to the sunspot cycle. It has been shown (MacLulich 1935) that the rabbit peak was reached in 1931 in part of south-eastern Ontario, but not till 1934 in northern Ontario. This situation does not suggest control by the sunspot cycle. The lags of the rabbit peaks after the nearest sunspot minima were (1856 to 1933): 0, −3, −3, −3, +6, +3, +1, +1, +1, and average +1/3 of a year, but the lags after the nearest sunspot maxima were: −4, +4, +5, +3, +2, −1, −3, −4, +5, and average +7/9 of a year. The coefficient of correlation of the Hudson's Bay Company rabbit figures from 1847 to 1903 with sunspot numbers is −0.08 with a probable error of ±0.09; and the coefficient for the whole period from 1847 to 1934 inclusive, is −0.08 with a probable error of ±0.07. This means the rabbit and sunspot curves are not related.

There are recurring periods during which the animal peaks or other phenomena correspond more or less closely to the sunspot maxima, each followed by a period when the animal curve is roughly in phase with the sunspot minima, as was pointed out above for the lynx. Authors have noted this correspondence, especially over periods of 50 years or less, and have assumed a significant correlation. There appears to exist a degree of cyclic correspondence among many animal populations, but it has been shown above that it does not correlate with sunspot numbers in the cases studied, where the history goes back far enough to allow definite conclusions to be drawn. The short, three to four year cycles of lemmings and other mice (Elton 1924) obviously are not caused by the much longer sunspot cycle.

Conclusions: 1. The Hudson's Bay Company fur returns as given by Poland (1892), Seton (1911, 1928) and Hewitt (1921) indicate the abundance of the animal as a result of the breeding season of the second year previous to that for which they were quoted in the above books. Certain corrections are demonstrated for the lynx and rabbit graphs in Hewitt's book (1921).

2. The fluctuations in numbers of neither lynx (*Lynx canadensis*) nor varying hare (*Lepus americanus*) are correlated with sunspots; but they are strongly correlated with each other.

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REVIEW OF PUBLICATIONS

Highlights of Astronomy, by Walter Bartky. 280, xiii pages. University of Chicago Press, 1935. Price $2.50.

This book by Dr. Walter Bartky, Associate Professor of Astronomy at the University of Chicago, will, in the reviewer's opinion, quickly find favour with both the beginner in astronomy and with the layman. Prepared as an introductory course for the "New Plan" undergraduate curriculum of the University of Chicago, the work undoubtedly commands special interest from educators on this continent.

The book, consisting of seven chapters, deals with the Earth, Time, the Sky, the Moon, Celestial Mechanics, the Solar System, the Sidereal Universe. One would expect that a volume of such modest size would necessarily confine itself to a descriptive treatment of these topics. The author, however, has introduced very skilfully into his volume a considerable body of practical astronomy. This he has done simply and non-technically and without sacrificing lucidity, accuracy or precision. Dr. Bartky's skill is particularly evident in the two chapters devoted to "Time" and to "The Sky", respectively, the treatments of which are not surpassed by those even in larger and fuller texts.

The author's scholarship and his ability as a teacher are evident in every page. Expert choice and co-ordination of material, delightful humour, fitting quotations, and a clear style combine to give an interesting book and a reliable source.

A large number of photographs from the Yerkes Observatory, a collection of unusual pen and ink sketches by Mrs. Chichi Lasley, and the inclusion of several charts, enhance the scientific and artistic values of the book. Dr. Bartky is to be congratulated upon producing this work of outstanding merit.

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University of British Columbia,
Vancouver, B.C.

Factor Table (*British Association Mathematical Tables, Volume V*) prepared independently by J. Peters, A. Lodge and E. J. Ternouth, and E. Gifford. Pages XV, 291, 8½ x 11 in. London, Office of the British Association, 1935. Price 20/.

To a number of mathematicians, engineers, actuaries and computers this volume will no doubt prove an invaluable aid. It is a table of the prime factors of the numbers up to 100,000. All numbers are included and the arrangement is such that any number can be looked up in a minimum of time. Moreover, unlike other tables of a similar character, this table gives the complete factorization of each number. Thus, for example, we find that $93288 = 2^3.3.13^2.23$. Primes are readily discovered, being indicated in bold-face type.

At the end of the factor table there is given, as a sort of appendix, a table of the reciprocals of primes less than 10,000. This is intended to be used in connection with a rapid method of discovering factors of numbers less than 100,000,000. With its help a skilled computer with a machine may examine a number for factors in a few hours. This will, perhaps, indicate the tremendous amount of labour which has gone into the preparation of the factor table and likewise the labour which may be saved by its use.

In the preparation of the table there were six proof-readings against three independent copies as well as comparisons with other published tables. The compilers believe that no errors exist in the printed table.

In the Introduction the work done by computers and readers is described, and it is evident that there has been patient, laborious and efficient co-ordination. In the Preface, Prof. E. H. Neville, the chairman of the B.A.A.S. Committee on Calculation of Mathematical Tables, states that Dr. L. J. Comrie has done more than anyone else to bring to a successful conclusion the preparation and publication of these tables.

The paper, printing and binding of the tables leave nothing to be desired.

J.F.H.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Meteor Spectra—List III

For the past two years lists of all known photographic meteor spectra have been published in these columns and an identifying numeral has been assigned to each spectrum. Though the writer knows of but one spectrum photographed in 1935 it is listed here for the sake of uniformity and in the hope that anyone knowing of other meteor spectra secured during 1935 will communicate at once with this department of the Journal. Poor observing weather at many stations was responsible for the small number of spectra photographed last year.

Photographic Meteor Spectra—List III

Spectrum	Date	Place	Identification
XXXIX	Nov. 18, 1935	Richmond Hill, Ont.	Leonid

Observations of the Lyrids at Bologna, Italy

An excellent set of Lyrid Observations has been received from that indefatigable observer, M. Eppe Loretta, located at Via Ernesto Masi 14, Bologna, Italy. Visual observations were carried out on the nights of April 19-20 and 21-22, 1936. The numbers of meteors (Lyrids and Non-Lyrids) appearing during fifty minutes of each hour were counted and are given in Table I. The magnitude distribution of these meteors is listed in Table II. The Lyrids, even if we

TABLE I

Lyrid Rates Observed at Bologna, Italy

M.E.T.	Apr. 19-20		Apr. 21-22	
	Ly	N Ly	Ly	N Ly
20.5h — 21h	0	1	2	6
21 — 22	1	3 (clouds)	7	8
22 — 23	4	7	7	7
23 — 0	6	10	8	13
.0 — 1	1	6	7	8
1 — 2	4	7	9	11
2 — 3	4	3	10	9
Totals	20	37	50	62
		249		

exclude the one bright fireball, were definitely brighter on the average than the Non-Lyrids. The very bright Lyrid, recorded at 1.33 a.m. on Apr. 22 and estimated as of magnitude –10, was not itself seen. M. Loretta estimated its luminosity by the brilliant illumination of the sky. He was able, however, to make very complete observations of the persistent train, which was visible to the naked eye for almost a minute and was seen in binoculars of 1.8-inch aperture for two and a half minutes after the meteor had disappeared. The interesting changes in the position and form of this train are shown in Figure 1. If the brightest part of this train appeared at the most common height for these objects, i.e., about 55 miles, its recorded motion of approximately four degrees in two minutes against the stellar background would correspond to a minimum

TABLE II

MAGNITUDE DISTRIBUTION OF LYRID METEORS

Mag.	−10	−1	0	1	2	3	4	5	Totals	Mean Mag.
Lyrids	1	..	..	4	10	22	29	4	70	3.1
Non-Lyrids	..	1	..	1	6	21	53	17	99	3.8

velocity of 180 miles an hour towards the west. Its true velocity was probably considerably greater than this as there is small probability that the motion was exactly at right-angles to the line of sight. M. Loretta is to be commended for the skill with which he recorded this phenomenon in the brief time at his disposal. The importance of such observations cannot be too highly stressed. They are very valuable clues in the solution of the problems of the upper atmosphere and it is sincerely hoped that all those observing such trains will report them, either to this department of the JOURNAL or to some observatory where meteors are being studied.

JAPANESE OBSERVATIONS OF THE LEONIDS

One of the purposes of this column is to call attention, from time to time, to important pieces of meteor research which have been published in various languages and are not easily available to those who read only the English periodicals. Well worthy of note in this connection are the Leonid observations published by Dr. M. Huruhata of the Tokyo Observatory in the Memoirs of the Astronomical Society of Japan, vol. 3, no. 4, 1935. This paper, which is in

Japanese, deals primarily with observations of the Leonids made in 1934 in the neighbourhood of Tokyo. A total of 31 observers took part in the programme and observations were made on 19 different nights from Oct. 27 to Nov. 24. In 144.6 hours of observing time 1761 meteors, including 941 Leonids, were recorded. The mean hourly rate of Leonids for a single observer rose to 17.5 on the morning of Nov. 17, being about half this figure on the preceding and following dates. This was compared with a maximum Leonid rate of 9 observed in 1933 and of 20 observed in 1932.

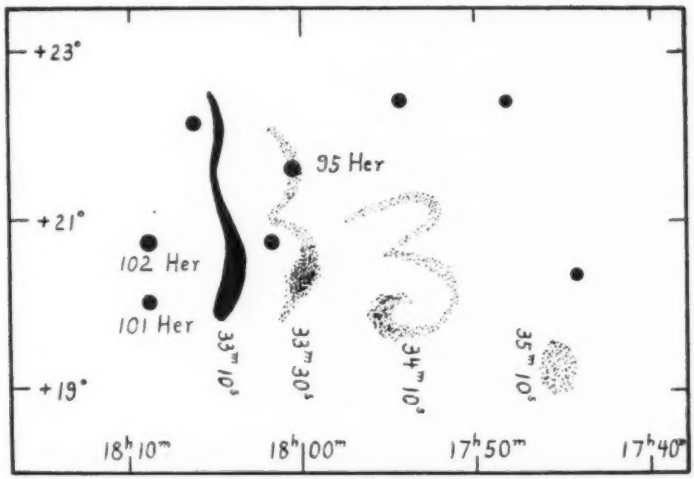

Fig. 1. Persistent train of Lyrid fireball which appeared near Bologna at 1.33 a.m., April 22, 1936.

Converting these rates to six observers and no moon by the factors previously published in these columns, we can compare them with the maximum Leonid rates determined at Harvard and Toronto and summarized in the January number of the JOURNAL.

MAXIMUM HOURLY LEONID RATES, SIX OBSERVERS, NO MOON

	1932	1933	1934
Harvard and Toronto	144	40	66
Tokyo	140	32	62

The agreement between these two absolutely independent sets of results is quite remarkable.

Dr. Huruhata computed the mean position of the Leonid radiant for the eight nights in 1934 when there was a sufficient number of observations to make a fairly accurate determination possible. The results are plotted in Figure 2 and clearly show the motion of the Leonid radiant occasioned by the change in the position of the apex of the earth's way. Radiants determined at Tokyo during 1932 and 1933 are also plotted in the diagram for comparison. The average deviation from the smooth curve of the eight mean radiants for 1934 was 0°.25 in R.A. and 0°.10 in Dec. These are very small for

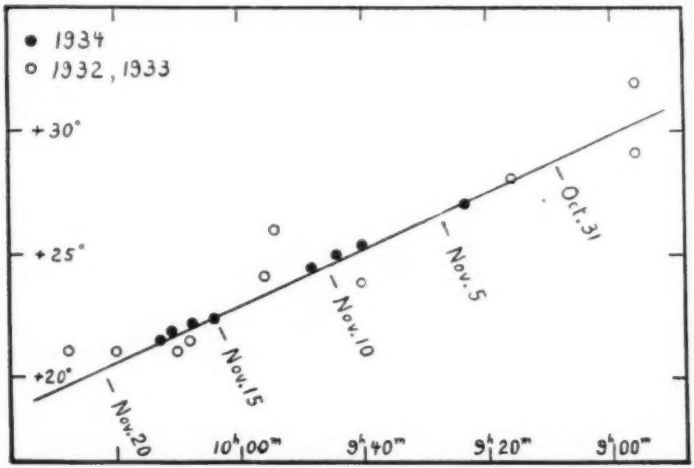

Fig. 2. Positions of the Leonid Radiant as observed at Tokyo, Japan.

radiants determined by visual means. Adopting R.A. 152°.5, Dec. +21°.5 as the position of the Leonid radiant at Nov. 16.^{d}8, 1934, G.C.T., the elements of the Leonid orbit were computed and agree very closely with those for Temple's Comet given by Crommelin. The two sets of elements, as published by Dr. Huruhata, are given below.

	Leonid Meteors	Temple's Comet
π	43° 51′	46° 30′
Ω	233° 45′	233° 54′
i	163° 32′	162° 41′
e	0.9053	0.9054
log q	9.9921	9.9910

P.M.M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Beyond the Stratosphere

Some of the statements in the lively article on travel through space, bearing the above title, by William Gifford Hale in our last issue (p. 175) have been questioned in various quarters.

A note has been received from Dr. C. C. Birchard, a member of the council of the Montreal Centre, in which, referring to the paragraph, "The heavens swing round" (p. 184), the following comment is made:

The author makes his celestial carriage turn end-for-end as it passes the point where the gravitational pull of the approaching moon becomes larger than that of the receding earth. He says: "We realise that all that has happened is that our car has turned over, as its heavy base is pulled around by the increasing attractive power of the moon". Obviously this is quite wrong. As the car approaches the line where the gravitational pulls of the earth and moon neutralize one another, each unit of mass in the car is travelling with exactly the same velocity, and its orientation in space must remain unaltered until one part acquires an acceleration not given to other parts. Since the gravitational pull of the moon on each unit mass of the car will be the same, every portion of the car will have the same acceleration from the moon's attraction, and no change of orientation will take place. Apparently, the author was not quite able to divest his mind of the idea of a gaseous atmosphere in space. An atmosphere in space retarding the car's motion might bring about the end-for-end change.

In the preceding remarks I have assumed that the gravitational effect upon each unit mass of the car by the earth and by the moon will be the same. Actually this is not quite true. If we consider the centre of gravity of the after-half of the car as separate and distinct from the centre of gravity of the forward-half, the acceleration of each unit mass in the after-half towards the earth will be greater than the acceleration of each unit mass in the forward-half. Accordingly, if for any reason the line joining the two centres of gravity of the car cease to pass through the centre of gravity of the earth, a couple will develop immediately tending to re-align the three centres of gravity—centre of gravity of the earth, centre of gravity of the after-half of the car and centre of gravity of the forward-half. The same reasoning appears to apply to the effect of the moon. It follows, then, that not only will the car not turn end-for-end when it reaches the neutral point, but that there will be a constant tendency to keep the car aimed away from the centre of gravity of the earth and toward the centre of gravity of the moon.

Then Dr. P. M. Millman takes exception to the description of the

encounter with meteorites wandering in space and to some other matters, in the following words:

In describing the experiences of an interplanetary traveller one must admittedly rely to a great extent on speculation. We should, however, make use of what scientific knowledge we do possess. Wm. Gifford Hale, in his account of a voyage to the moon published in the last number of the JOURNAL, describes the effect of meteors on the space-ship in the following words: "In sharp staccato raps, like those of a rifle barrage, single, double, and quickly repeated shots, rising sometimes to a rattle of musketry, comes the assault of the meteorites of space,—" (p. 180). To say the least, this is a very exaggerated picture. It is not difficult to compute approximately the probable number of meteoric impacts experienced by the space-ship in its journey to the moon. If we take all meteors down to fifth magnitude we include all objects greater than a millimeter in diameter. As a generous estimate one such meteor is visible per minute from any point on the earth's surface and we can assume that this number includes all meteors entering the atmosphere within a radius of 150 miles. The ratio of this area on the earth's surface to that of the cross-section of a space-ship 40 yards in diameter is roughly 2×10^8, and assuming the velocity of the space-ship and of the earth to be of the same order of magnitude we find that on the average the space-ship would only encounter one meteor larger than a millimeter in diameter in a journey of four or five hundred years. Even supposing the meteors to be a million times more numerous than given by the above calculations (a density probably several hundred times greater than that at the centre of the great Leonid shower encountered in 1833) the space-ship would still only strike one such object on its whole journey to the moon.

In speaking of Wells's story of a journey to the moon Hale says: "The idea of life beneath the moon's surface, the ever-blowing winds of the interior caves, the central sea, the idea of the frozen atmosphere in the craters, and the life there, all agree most finely with latest ideas of those astronomers who are not afraid to use their wits —" (p. 176). The foregoing sentence might lead one to believe that reputable astronomers actually support such views. On the contrary it is very doubtful if even the most visionary astronomer would seriously consider the above product of the imagination. One must be careful to draw a distinct line between that sort of composition which has been aptly designated "scientifiction" on the one hand and, on the other, an honest attempt to describe the extra-terrestrial universe based on the actual facts of astronomical observation.

In connection with this same article it should be noted that, while minute second and third satellites of the earth must be admitted as a possibility, they should not be referred to as already known (p. 181). As a matter of fact there is at the present time not a bit of definite scientific evidence to back their existence. A space traveller would also find considerable difficulty in making out the shape of the continents when looking back at the earth, as it would be a very rare occurrence indeed for the visible hemisphere to be appreciably free of cloud (p. 182). Our atmosphere in the zenith cuts down the magnitude of the stars by less than half a magnitude; hence, instead of the 6000 stars visible

over the whole sky from the surface of the earth, we might see some 10,000 from our space-ship,—hardly an increase from hundreds to thousands. In addition to this, it must be remembered that out in space we would lose all the beautiful twinkle of the stars and the refraction effects caused by our atmosphere, while the stars would not be noticeably more monochromatic. The sight might then not even rival that of a clear night in the tropics.

Cash Prize for a Manuscript on a Science Subject

Prizes for fiction, poems or other literary material are relatively common but publishers do not usually bid for science productions in this way. However, The Williams and Wilkins Company of Baltimore, Maryland, offer $1000 for a science MS. in English "of a sort calculated to appeal to the taste of the public at large", to be ready before July 1, 1937. The desired length is about 100,000 words, but the subject-matter and the manner of handling it, as well as eligibility for the award, are without limitations. Further details are available from the publishers.

Solar Eruptions and Terrestrial Phenomena

Since about the middle of last century it has been generally accepted that sun-spots are closely related to disturbances in the earth's magnetism, but there have been few observations of single disturbances occurring simultaneously in the sun and the earth. One such is reported in *Science* for May 15, 1936.

At Huancayo, Peru, is a magnetic observatory of the Carnegie Institution of Washington, and on April 8, 1936, at 16.45 G.M.T. by means of the spectrohelioscope activity was first noticed surrounding the largest sun-spot of a group of about six. This increased until 16.47 and soon after this it was noticed that three other smaller spots in the group had become mildly active. By 17.03 the flocculi about the spots had returned to their original appearance.

The photographic records of the three magnetic elements showed a sudden disturbance at 16.46. The four earth-current records were proceeding smoothly until 16.45 when they all showed radical changes. Still further, the radio reception records of reflection from the ionosphere gave nothing exceptional until 16.45 when no reflections could be obtained at a frequency of 6400 kc. One can hardly doubt that there was a relation between the solar and terrestrial phenomena. This is an isolated case but as there were many elements involved and all seemed to be simultaneously affected there is strong reason for believing there was a cosmic connection between them.

C.A.C.

MEETINGS OF THE SOCIETY

AT TORONTO

The following were elected Members at Large:

DURING FEBRUARY

C. O. Arthur, 4103 12th Street N.E., Washington, D.C.
D. Babcock, 880 Marion St., Denver, Colorado.
R. Baldock, Blacksburg, Virginia.
L. I. Buttles, 10728 S. Artesian Ave., Morgan Park P.O., Chicago, Ill.
J. L. Hinds, Rio Grande, Texas.
R. A. Holsinger, 101 Plank Road St., Hollidaysburg, Pa.
J. C. Meyer, 1919 Lake Drive, Cudahy, Wis.
L. G. Stoddard, Student's Observatory, University, Berkeley, Cal.
Miss G. M. P. Taylor, High School, Thorold, Ont.
W. G. Worley, 36 Havelock St., Mayfield, N.S.W., Australia.

DURING MARCH

W. Mayer, 211 Murray Ave., Larchmont, New York.
Prof. Dr. F. Průsa, Hradec, Králové, Czechoslovakia.
W. H. Stilwell, 61 Grosvenor St., Toronto.

DURING MAY

Ricardo Arámburu, Argentine Consul, Wakoe Building, Honcho-4, Yokohama, Japan.
W. H. Barton, Hayden Planetarium, Central Park W., New York City.
N. J. Heines, 560 Broadway, Paterson, New Jersey.

March 31, 1936—The regular meeting was held in the McLennan Laboratory, University of Toronto. Mr. A. R. Hassard was in the chair and the attendance was exceptionally large.

Mr. Philip Perry, Huttonville, Ont., was elected a member of the Society.

Mr. H. G. Duncalfe gave an explanation of the meaning of the parallax of a star and showed how minute the measured angle is, in the case of a star.

Dr. J. Satterly, Department of Physics, University of Toronto, gave an illustrated lecture on the Age of the Earth. He showed how an estimate of the age of the earth could be obtained from astronomy, geology and radioactivity.

In astronomy, on the assumption of the nebular hypothesis or the tidal theory, the age of the solar system is estimated to be about 3,000 million years. The time taken by the moon to recede to its present position gives another value. Also some meteors have been found which show from radioactive considerations an age of 2,800 million years.

Slightly more definite results as to the age of the earth's crust can be determined geologically, by studying the amount of sediment carried down by rivers, and by the ages of the different layers of rock. This gives an idea of the time elapsed since the earth's crust solidified out, about 1,700 millions years.

Joly determined the age of the ocean as 330 million years from analyses of its salt content and the amount brought down yearly by rivers. Another method is to determine, on the rules of thermodynamics, the time taken for a cooling sphere to reach the earth's present thermal state.

However, the most definite results come from the field of radioactivity. The three radioactive families, Uranium, Thorium and Actinium, each end in lead, after several transformations. Knowing the rates of decay of each element, and the rate of growth of the lead deposit, rocks containing both the radioactive parent and its lead can be analyzed and the time deduced, necessary for the amounts present to have accumulated. During the transformations alpha particles are given out, which, being helium nuclei, cause the accumulation of this gas in the rock. Analysis of the quantity of this gas present in the rock also gives an estimate of the time since the radioactive parent started to give off alpha, beta and gamma radiations.

From all these methods the age of 2,000 to 3,000 millions of years is derived as the most probable age of the earth.

April 14, 1936.—The regular meeting was held in the University of Toronto, Mr. A. R. Hassard in the chair.

The paper of the evening,—"Concepts of Velocity, Acceleration, Energy and Potential", was given by Prof. S. Beatty, of the Department of Mathematics, University of Toronto. Prof. Beatty showed how Newton arrived at the components of velocity and acceleration of a moving point in any direction by means of the calculus. He showed the existence of the velocity circle and the acceleration circle and also the relation between the parallelogram of velocities and the velocity circle and the difference between them. Taking Newton's Second Law, $F = ma$, Dr. Beatty pointed out that Newton was aware that this equation held in each direction, or that the component of force in any direction is equal to the mass times the component of acceleration in the direction. Taking the case of the simple pendulum, and using this formula, first at right-angles to the string, and then along the string, Dr. Beatty developed an expression for the tension in the string. Also taking the case of a central orbit, the differential equation of motion, showing that equal areas are swept out in equal times by the radius vector, was obtained. In the case of a spherical shell, Newton was aware that a particle within would be at rest, and Dr. Beatty showed how Newton arrived at this conclusion. Also when the point was outside the sphere, the sphere acted as though its mass were all concentrated at the centre. Newton arrived at this conclusion also but later potential theory proves this more satisfactorily.

Mr. Horning gave another talk on the seasonal changes in the heavens, showing how the winter constellations have shifted westwards and the spring constellations have taken their places. Taking the constellation Leo, at present the most conspicuous constellation well up in the evening, Mr. Horning related legends about it and gave points of interest concerning the stars Regulus and Denebola, and also the beautiful little open cluster, Praesepe in Cancer.

Mr. H. B. Collier, of Viking, Alta., reported some fine lunar halos, a drawing of which he sent the Society.

The Librarian, Dr. P. M. Millman, sent in the announcement that the library had acquired two new books, "Stars and Telescopes" by James Stokely, and "Worlds Without End" by Spencer Jones.

April 28, 1936.—The regular meeting took the form of a visit to the David Dunlap Observatory, Richmond Hill. The meeting assembled in the lecture room of the Observatory, Mr. A. R. Hassard in the chair.

The following were elected members: Mrs. S. J. Sweetman, 43 Hillside St., Belleville, Ont.; Mr. Jack Bougard, 12 Lansdowne Ave., Toronto.

Dr. Chant, Director Emeritus of the David Dunlap Observatory, gave an informal talk on some incidents of his recent trip to Florida. While at St. Petersburg, he noticed that the line through the ends of the horns of the new moon made quite a different angle with respect to the horizon than it does at our latitude. He also told us of the beautiful Bok Singing Tower with its carillon and vertical sundial. His trip also included a visit to the Naval Observatory at Washington, which makes a specialty of transmitting the correct time, using a unique automatic system of their own design.

Dr. Young, Director of the Observatory, then outlined to the meeting the work of the Observatory during the last year, mentioning the difficulties accompanying the first work with such instruments.

Following this, Dr. Millman showed how the large 74-inch reflector is manipulated. The weather being unfavourable, it was not possible to view any astronomical objects.

Refreshments were served in the Administration Building, which was open for inspection.

F. SHIRLEY PATTERSON, *Recorder.*

AT VANCOUVER

March 10, 1936.—The 38th regular meeting of the Centre was held at 8.15 p.m., Mr. C. A. McDonald presiding.

The speaker of the evening was J. G. Davidson, B.A., Ph.D., of the University of British Columbia; his subject was "Colour". Dr. Davidson opened his lecture by making reference to the fact that astronomers were particularly interested in light as no progress could be made in astronomical research without the study of light and colour. Light travels in wave forms similar to sound waves and electrical waves, the length of the wave being determined by the distance between the succeeding crests of the waves. A lantern slide was thrown on the screen depicting wave motions during this portion of the lecture, showing the difference between the short waves and the long waves associated with light and electrical waves.

Light, it was explained, first strikes an object and is then reflected to the eye, forming an image or colour. An explanation was given of the sensation of colour as it is conveyed by the optic nerve centre to the brain. A portion of the optic nerve, consisting of cone and rod-like nerves, was responsible for

transmitting the colour sensations to the brain, defective nerve centres and damaged rods or cones being responsible for colour blindness, as each rod and cone-like nerve would function with different colours. A number of demonstrations were then given of light reflection, both direct and indirect. A gold leaf was placed before a beam of light, demonstrating the yellow reflection, and the transmission of green light through the gold leaf, as an example of partial reflection and partial transparency, and absorption. A comparison was given between the spectrum of artificial light and visible sunlight; also, by use of the prism and slit, a beam of light was used to display the succession of colours in the spectrum and an explanation of the infra-red and ultra-violet ends of the spectrum was given. The spectrum of neon was displayed on the screen as an example of the method used to recognize the various gases and minerals present in stars. By use of the radiometer long waves invisible to the naked eye passing through dark glasses were demonstrated, also fluorescence effects by ultra-violet waves.

The mercury arc and its effect on the red portion of the spectrum, and the partial destruction of some intermediate colours was demonstrated. Also there was a demonstration of the sodium vapour lamp now being used, it was explained, in dangerous traffic spots on account of no shadows being formed when in operation; all colour was destroyed by this lamp, and its effect on the appearance of the members was very startling. Dr. Davidson concluded his very interesting lecture by giving demonstrations of various colours as they appeared to colour-blind persons, along with a lucid explanation of the causes of colour-blindness, making the statement that one person in three was red colour-blind and every sixteenth person green colour-blind.

April 14, 1936.—The 39th regular meeting of the Centre was held at 8.15 p.m., Mr. McDonald, the president, in the chair.

Mr. J. C. Jorgensen, the first speaker, gave a talk on the making of a refracting telescope; he had on display a 5-inch refractor of 90-inch focal length, mounted on a tripod with clock drive, all made by himself. The speaker explained that it was not always possible to make a refracting type of telescope free from colour in its transmission of light, the best professional pair of achromatic lenses made would always show a slight purple halo or secondary spectrum round the images of bright stars, and as a border to the disks of planets. This is on account of the spectrum being more dispersed at the violet end than at the red end, and a little of the violet light is therefore left outside the correction in all combinations of the flint and crown glass discs in all properly calculated curves worked out by telescope makers.

The curves used by Mr. Jorgensen in his lenses were an equi-convex crown glass and a plano-concave flint glass, the concave side of the flint glass being equal in curvature to the two sides of the crown glass. This made three curves of the same radius and one flat side to grind and polish, and saved a lot of figuring and changing of tools. The concave side of the flint glass was ground on one of the sides of the crown glass. The flat side was tested for flatness by the Newton's rings method of testing with sodium light.

Mr. Jorgensen stated that amateurs should purchase their blanks from a reliable lens-maker, and should order the type required. Full information in regard to this will be found in "Amateur Telescope Making", published by the Scientific American Co. Also care should be taken to see that the edges of the lenses are of uniform thickness during the grinding; a very novel type of thickness gauge was made by Mr. Jorgensen and described at the meeting. Also Mr. Jorgensen used during the testing of his lenses for correcting a home-made spectroscope with slit, and a solar spectrograph slide in colour taken through the slit was shown on the screen. This displayed the portion of the spectrum which could not be corrected as previously explained.

Mr. Jorgensen concluded his address by stating that while a refractor did not give the clear colourless images that a reflecting mirror gave, it permitted more light to be transmitted, and was superior in performance in many other ways, and he recommended his listeners to grind and polish a pair of crown and flint glasses after they had made at least one reflector.

The next speaker, Mr. J. Teasdale, gave a short description of the methods used by him in finishing his parabolic mirror by the use of masks over certain zones in making knife-edge tests.

Zonal testing, Mr. Teasdale explained, gave better results than trying to arrive at a decision that the whole surface of the mirror was correctly figured. By testing the edge and the centre separately, with the other portions of the surface covered, and allowing for one-tenth of an inch between the centre of curvature at the position where the central zone and the marginal zone show an even shadow under the knife-edge test, one could be sure of having a parabolic mirror that would perform satisfactorily for any amateur. Mr. Teasdale displayed samples of masks used by him in the making of several 6-inch mirrors, and also showed sketches of the darkened shadows appearing at the different zones in a perfectly corrected mirror.

A description of the arrangement used for cutting the shadow at the centre of curvature was explained by Mr. Teasdale, also the micrometer-testing device he made to plot out his surfaces to a close degree of accuracy.

Mr. Teasdale referred his listeners to the article written by Dr. R. K. Young that was printed in the JOURNAL dated January, 1930, in which some very valuable information regarding the testing of mirrors by the zonal method was given. In conclusion Mr. Teasdale urged the members to bring any problem regarding grinding of mirrors to him and he would be very glad to assist them, and as chairman of the telescope-makers' section of the Vancouver Centre urged amateurs now making mirrors to get together with their problems and troubles and not to try to grind and polish away in solitude as so many appear to be now doing.

The third speaker of the evening, Mr. Thrupp, gave a brief description of some auroral displays which took place on Jan. 15, and Oct. 18, and which he had previously predicted at a meeting of this society on Oct. 18, 1935. Mr. Thrupp stated that his predictions of these displays had been confirmed by the Meteorological office at Victoria, and he had also obtained confirmations of the auroras taking place at Kamloops and in Idaho, on the same dates.

By means of charts and records kept by Mr. Thrupp over a period of many years, showing the fluctuations in the magnetic needle immediately prior to the displays taking place, he was able to predict the appearance of auroras, he said, for years in advance. He also stated that he had a different theory for the cause of auroras from those generally given in scientific works such as being related to sun-spots and electrical phenomena. Mr. Thrupp hoped to complete a book in a few months which would give his theory. Attention was called by the speaker to the fact that earthquakes and earth tremors usually followed auroral displays.

Mr. Thrupp was by profession a civil engineer, and an examination of his magnetic needle by the secretary a few days previous to an occurrence showed the needle deflected considerably to the west and Mr. Thrupp explained that his charts would show these fluctuations recurring at certain dates and it was no effort for him now to predict auroras for years in advance.

J. W. Moore, *Secretary.*

AT VICTORIA

February 6, 1936—The first regular meeting of the Spring Session of the Victoria Centre, R.A.S.C., was held in the Y.W.C.A. Parlors, commencing at 8 p.m. President Tingley occupied the chair. The President asked the audience to rise for a moment's silent tribute to the memory of our late King, George V.

The President announced a prize contest for amateur members of the Society. The sum of $10.00 has been offered by a member who wished to remain anonymous. The object of the contest was to promote an interest in the study of astronomy. The rules of same were read. Mr. Brydon presented a number of books from Mr. Collins of Toronto, which were formally received with thanks. The Observers' Handbook was discussed by Mr. Peters, who called attention to the various tables and useful information indispensible to the amateur observer. President Tingley then introduced the speaker of the evening, Dr. J. S. Plaskett, who gave a delightful lecture on the subject "Some Sidelights of Astronomy in Europe". The lecture was informal and well illustrated by lantern slides. Dr. Plaskett referred in his opening remarks to the jubilee celebrations as being a wonderful demonstration of devotion and affection of the British public toward the Royal House. A visit to the Royal Observatory at Greenwich by the King and Queen in 1925 was recalled, the occasion being the 250th anniversary of the Royal Observatory. Dr. Plaskett told of meetings of the Royal Astronomical Society where highly technical papers were read and discussed by eminent astronomers such as Jeans, Eddington and Milne. He told of the British Astronomical Association which operated on similar lines to our own Society, being composed, for the most part, of amateurs.

Dr. Plaskett's main participation in astronomical activities in England was his delivery of the Halley Lecture at Oxford on "The Dimensions of the Galaxy", a printed copy of which he presented to the Society. Humorous references to the hospitality of their hosts provided an amusing human touch to the lecture.

Dr. Petrie proposed a hearty vote of thanks to Dr. Plaskett for his interesting address, which was seconded by Mr. Robert Peters.

February 25, 1936—A regular meeting of the Society was held in the Y.W.C.A. Parlors commencing at 8 p.m. Comdr. Tingley presided.

Mr. Robert Peters gave a brief description of the constellation of Orion, calling attention to its many interesting stars and to the fact that it was now in the best position for observation. A marked sun-spot activity was also reported.

The speaker of the evening was Mr. James Duff, whose subject was "Curiosities in Numbers". He recounted Zeno's paradox of the race of Achilles and the tortoise whereby Zeno contended that because of the infinite number of phases involved Achilles could never catch up to the tortoise. The speaker pointed out that an infinite series would have a finite sum and therefore would solve the problem that had puzzled mathematicians and philosophers of the past. Mr. Duff showed how Archimedes in his sand reckoner had developed numbers large enough to express the number of grains of sand that would fill the universe. Newton's estimate of the distance of Sirtus by computation of the amount of solar light reflected by the outer planets was 100,000 astronomical units and was shown to be a fairly close approximation of its distance. Curious combinations of numbers propounded by Prof. Asaph Hall were presented, and finally a glimpse into the gradual accumulation of vast wealth produced by even low rates of interest over a long period of years.

Dr. Harper and Mr. Peters moved and seconded a vote of thanks to Mr. Duff for his address.

March 10, 1936—At the regular meeting of the Society, held in the Y.W.C.A. Parlors, the chair was taken by the president, Comdr. Tingley. Robert Peters, with the aid of Teddy Roberts, gave the younger members a demonstration of rapid addition of large numbers.

The subject of the evening, "Recent Developments in the Making of Large Telescopes", took the form of a symposium. Those taking part were Mr. Ronald Hopkins, who described the optical developments; Mr. W. R. Hobday, who stressed the mechanical improvements, and Mr. Robert Peters, who, by means of lantern slides, showed some results of these developments.

Mr. Hopkins traced the history of the telescope from Lippershey, the Belgian spectacle-maker who is credited with its discovery, to its gradual improvement through the hands of Galileo, Huyghens, Hadley, Short, Herschel, Foucault and several others. The relative values of the refractor were compared with the reflector showing that besides being easier to make the reflector presented less cumbersome housing. Its great disadvantage of small field due to coma was being overcome by corrective lenses, while another drawback, namely, the rapid deterioration of its silver coating, was being solved by a new aluminizing process. Mr. Hopkins created considerable interest by his reference to the telescope of the future. He suggested that the 200-inch came very near to the limit in size and that the experiments of Zworykin of Camden, N.J.,

in television pointed to the time when light would be amplified as sound is at the present time. Several diagrams of such an apparatus were shown on the screen and clearly explained.

Mr. Hobday followed with a description of mechanical improvements of the telescope. He compared one of the first large refractors, 150 feet long trussed up to a 90-foot spar with block and tackle, with the nicely-balanced, clean-cut design of the 72-inch reflector on Observatory Hill, Victoria. The mechanics of clock drives were explained, the newer ones being controlled by electric motors. An early Chinese observatory was shown on the screen and then in contrast the artistic building of the Yerkes Observatory. Mr. Hobday stressed the fine engineering skill evidenced in the modern observatory. In concluding the symposium, Mr. Peters showed some excellent slides of great star clusters and nebulae with their myriads of suns, some shown being of the 20th magnitude.

Mr. H. Boyd Brydon and Dr. C. S. Beals proposed and seconded respectively a vote of thanks to the three speakers, both mover and seconder paying tribute to the excellent presentation.

March 31, 1936.—A regular meeting was held in the Y.W.C.A. Parlors, commencing at 8 p.m. President Tingley was in the chair and called on Mr. Robert Peters for his talk on "Current Phenomena of the Sky". Mr. Peters described the constellation Cepheus with its mythology, its doubles and variables.

The speaker of the evening was Dr. W. E. Harper, whose lecture was entitled "The Solar Cycle and some Terrestrial Effects." In a certain sense, the lecturer maintained, we are all "children of the sun", inasmuch as its rays are the source of all power and life upon the earth. While the sun is simply one of millions of stars, it is the only one close enough to examine in detail, and from the days of Galileo to the present its surface has been carefully scrutinized.

The sun-spots, discovered by an amateur to be cyclic in character, having a maximum about every eleven years, were with the aid of lantern slides described in detail. They are vast eruptions like volcanoes on the sun's surface out of which are ejected gases consisting of matter in a very finely divided state. Surrounding these spots are strong magnetic fields whose recent study has shown that the true cycle of change is really double that previously accepted. Some internal cause, not yet sufficiently well understood, gives rise to the spot eruptions.

Coincident with the waxing and waning of the numbers of spots, it is found that the amount of radiation received from the sun varies from five to ten per cent. It is greater at sun-spot maximum than at minimum. Many attempts have been made to use these long-period variations in output of solar energy to predict weather changes for a long time ahead. The problem is very complicated, but Abbot, who has worked on this problem for thirty years, feels hopeful of a successful outcome.

The speaker mentioned one interesting result of the variations of solar energy as exemplified in the cyclic growth of trees, as shown by their rings, the growth being dependent upon factors of rain and sunshine which in turn are dependent upon the variations in the sun itself. About forty slides were used.

April 21, 1936.—The meeting was held at the same place and hour. Commander Tingley occupied the chair. The speakers of the evening were Capt. Wm. Everall, Wm. Petrie and A. S. Deacon, who presented a symposium on "Effects of the Sun-spot Cycle on Radio Reception, etc."

Capt. Everall, the first speaker, reviewed the nature of sun-spots, their distribution and periodicity. It was shown that the spots had magnetic fields. He traced the discovery of the earth's magnetism and the importance of that discovery. There was a close connection between magnetic storms and the sun-spot cycle, magnetic storms increasing when the cycle was at maximum. Capt. Everall concluded with the philosophical remark that since *we* are composed of electrons, we can find a kinship with each other and the whole of nature.

William Petrie dealt with the aurora. Halley thought it was some kind of self-luminous magnetic vapour. Then for a long time it was thought to be due to dust particles in the upper air. This idea was strengthened by finding deposits of oxide of iron in arctic snows. However, the spectroscope dissipated this theory by revealing in the aurora hydrogen and oxygen lines. The aurora was caused by ionization, the upper strata of the air being comparable to a Crookes tube; hence it is believed it is the release of energy due to ionization that produces the auroral light. By means of slides the relation between sun-spot cycles and auroral displays was clearly shown. The so-called audibility of the aurora was questioned.

Mr. A. I. Deacon concluded the symposium with a description of radio waves. He described the ionized layer of the upper atmosphere as the ionosphere and showed by diagram how radio waves were generated and on reaching the ionosphere were reflected back to earth. Owing to the varying height of this ionized layer, the distances of radio signals varied, there being skip-gaps at various points. There were times when so-called "night effects" interfered with radio direction-finding, making its value nil for the time being. Discussion on radio direction-finding, the aurora australis, and the audibility of the aurora took place.

GORDON SHAW, *Secretary.*

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